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A DOUBLE CONTRAST METHOD FOR THE ROENTGEN EXAMINATION OF ESOPHAGEAL STRICTURES

by

Hans Freidenfelt

It is often difficult in esophageal stricture to determine the length of the narrowed segment. This is mainly due to the problem of defining the lower border of the stricture. The lumen is frequently so narrow that only thin barium will pass through it, the poststenotic filling being inadequate for radiographic evaluation.

For better poststenotic filling of the esophagus, several workers have recommended examination with the patient supine, sometimes in the oblique Trendelenburg position with contrast filling of the stomach. MARCHAND (1952) described a similar method but with strong compression of the filled stomach in addition. Several other workers have described a double contrast method to facilitate visualization of the limits of the stricture. CHIZZOLA (1930) filled the stomach with air or carbonic acid, and then, after swallowing barium, the patient was induced to regurgitate the gas. The same technique has also been tried at this hospital. However, only a few patients can be persuaded to belch to order. PALUGYAY (1933) pointed out that double contrast films may be obtained if the patient swallows only a small amount of contrast medium, a certain amount of air being swallowed along with the medium; the author was able to obtain satisfactory dilatation of the esophagus in a few cases. According to SCHATZKI (1933), air filling of the entire intrathoracic esophagus by this means is rare and is usually seen only in cases in which the esophagus is atonic. JACOBS (1955) also recommended a double contrast method, and stated: "The double contrast films have additiona

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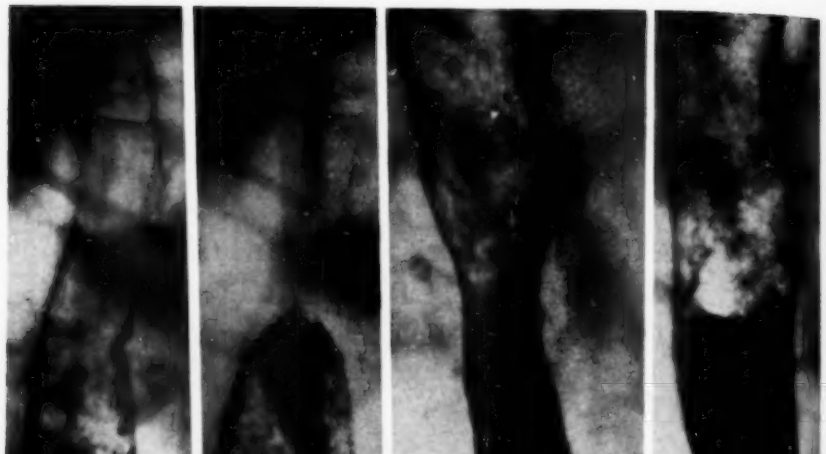

a b c d

Fig. 1. Control case. A 59-year-old male examined with effervescent powder swallowed with thin barium. This exemplifies the variations in dilatation sometimes observed in two successive exposures. a, b) Upper segment. c, d) Lower segment of esophagus.

value in that they present the endoscopist with an accurate idea of the distensibility of the esophagus and position and length of any narrowing of the lumen he will encounter." DINKIN (1930) proposed that hydrogen peroxide be added to the barium, on contact with a bleeding surface, barium foam is formed and fills the poststenotic segment of the esophagus.

Method

For about one year we have been using a double contrast method which in most cases has provided good distention of the esophagus, including the segment distal to the stricture. The method complements the routine examination and has been employed mainly in cases of constricting tumors of the esophagus, but also in strictures resulting from corrosion and from esophagitis.

In cases of severe stricture we first checked that no great amount of contrast medium had stagnated in the stricture after the routine exam-

ination. If there was much hold-up of barium, we deferred the double contrast examination, sometimes letting the patient rinse the esophagus with water. The examination was performed in the upright oblique position. The patient held a glass containing a little thin barium emulsion in one hand close to the mouth. We then placed a teaspoonful of an effervescent powder (sodium bicarbonate and tartaric acid, equal parts) in the patient's mouth, after which he immediately washed down the powder with a small swallow of the contents of the glass. Carbonic acid was formed as soon as the water in the barium emulsion came into contact with the powder, this resulting in dilatation of the esophagus. Following a quick fluoroscopic control of the projection, four to six exposures were made in rapid succession. The distention may change from one moment to the next in the different segments due to contractions of the esophagus. However, if several exposures are made, these variations in the lumen will not cause difficulty in evaluating the films (Fig. 1). The patient should be given thorough instructions beforehand as to what is expected of him.

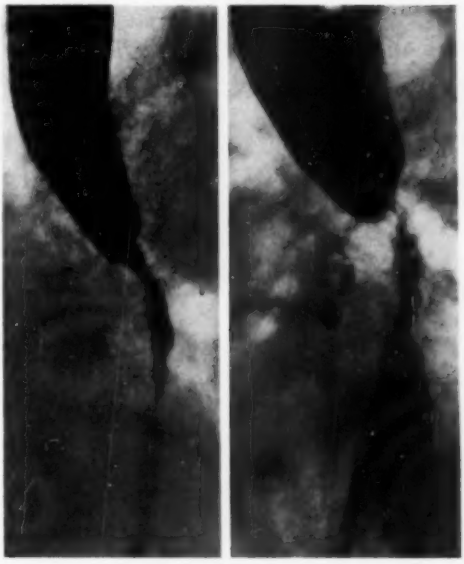

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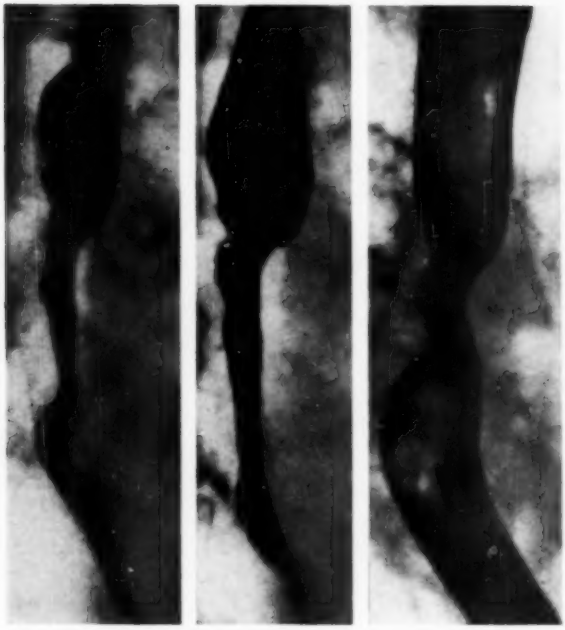
Fig. 2. Constrictive tumor in central segment of esophagus. a) Thin barium contrast is flowing slowly through the stricture with no filling of poststenotic area; no indication of length of stricture. b) Poststenotic segment dilated with effervescent powder and thin barium; length of stricture can be gauged.

As a rule we used a full teaspoon of the powder, but a somewhat smaller quantity was given if the obstacle was at a high level or just below the suprasternal notch. The method was usually not applied in strictures above the suprasternal notch, for example in the inferior portion of the hypopharynx, since there is a risk that the barium foam will be inhaled. The process could be repeated without discomfort to the patient three or four times within the course of the same examination. However, too much of the powder caused considerable gas formation in the stomach, and after some practice we found that one teaspoonful, or approximately 4 grams of powder, usually sufficed for the exposures which could be made while inflation was maximal.



a b c

Fig. 3. Stricture resulting from tumor in central segment of esophagus treated with irradiation. a, b) Apparently relatively long stricture observed with ordinary barium. c) Distension with effervescent powder reveals esophagus to be widened proximal and distal to stricture which is actually only 3 to 4 cm in length.

With the help of a Philips image intensifying tube I made a motion film of the examination in a few cases and found that the dilatation of the normal esophagus lasted for approximately 6 to 8 seconds. If passage was difficult due to stricture, the dilatation remained more than twice as long, *i. e.* approximately 15 seconds.

Material

The method was used in 104 cases. The diagnosis was cancer in 69 cases, cicatricial stricture in 12, esophagitis with stricture in 6 and achalasia in 2. There were no roentgenographic changes in 15 cases (controls). Thirty-eight of the cancer cases comprised newly discovered tumors, while the remainder were examined during or after radiation therapy. Some of the cases were thus examined more than once, and the method was used 140 times in the 104 cases. The tumor was situated

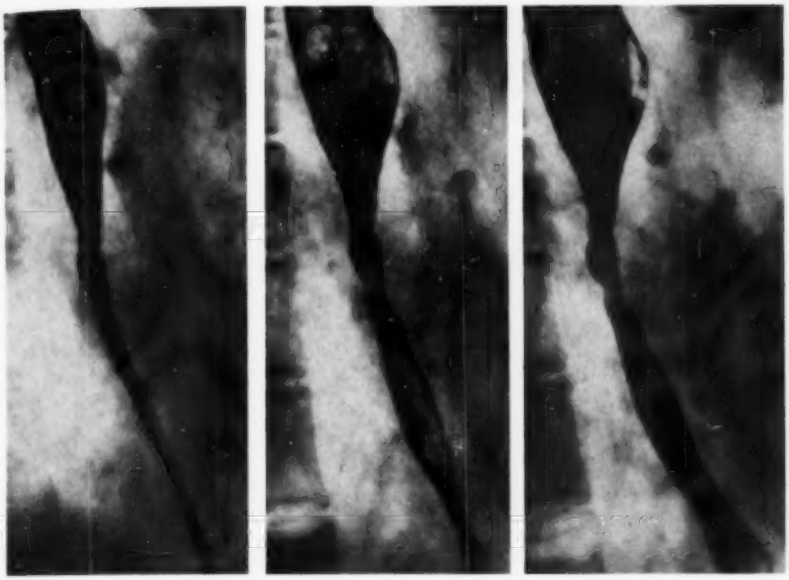


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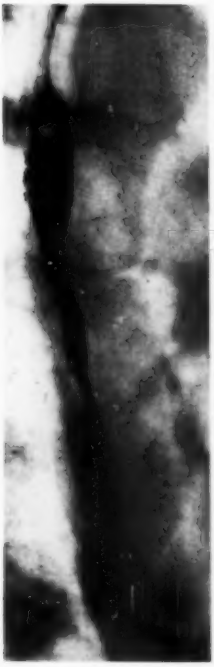
Fig. 4. A 40-year-old female with cicatricial stricture caused by a corrosive 15 years previously. a) Routine examination shows no dilatation at distal end of long stricture in lower part of esophagus. b, c) Distal end of stricture dilated with effervescent powder.

in the upper third segment of the esophagus in 12 cases and in its middle or lower third in the remaining 57 cases.

The method was not used if deglutition was defective. Nor was it applied to young children, since it requires cooperation from the patient. As already mentioned, this examination is not suitable for strictures in the hypopharynx.

Results

Greater dilatation of the lumen was secured with this method than with the usual barium emulsion technique in 97 of the 104 cases. The dilatation of the poststenotic segment so obtained permitted clearer definition of the lower border of the stricture (Figs. 2 and 3). In a few cases slight dilatation of the lumen could be observed in the area of the stricture itself (Fig. 4). Mild strictures which were almost or entirely imperceptible with the routine examination were clearly visible when the prestenotic and poststenotic segments of the esophagus were inflated



a b

Fig. 5. Cancer of esophagus two months after irradiation. Slight stricture at site of tumor, a few centimeters below arch of aorta. a) Stricture scarcely visible with ordinary barium. b) Stricture fully visible with distension of esophagus.

a b

Fig. 6. Ulcerated cancer in middle and lower part of esophagus. Examination before treatment. a) Routine thin barium swallow. b) Distension by double contrast method. Lumen dilated within tumor area, indicating that the tumor has not invaded entire circumference. Note fistula in upper part of tumor which is more clearly defined than in (a).

(Fig. 5). The examination could not be carried out in five cases because of the patient's condition (age, debility, poor general condition). Dilatation was no better than with ordinary barium contrast in two cases, presumably because of faulty technique.

Complications

There were no complications even in cases with large ulcerated tumors (Fig. 6). If the dose of powder was too large, a few patients suffered mild discomfort from flatulence.

Discussion

Good dilatation of the esophagus may occasionally be obtained by swallowing air only. With the double contrast method described, on the other hand, the examiner can almost invariably achieve dilatation of the esophagus, even distal to a stricture, in cases in which the method is practicable. This is, of course, conditional on the esophagus not being completely blocked. The method enables us to define the lower border of the stricture, and thus also to determine the extent of the stricture as well as other changes in the poststenotic segment (Fig. 7).

Fig. 7. Old corrosive injury in 30-year-old male. Inflation reveals two long strictures with intermediary area normally distended. Note widening of esophagus at level of suprasternal notch and down towards cardia.

SUMMARY

A double contrast method for the roentgen examination of the esophagus is described. By swallowing effervescent powder together with a thin barium emulsion, carbonic acid is produced in the esophagus, which is thereby inflated. The method, which has been used without complications in approximately 100 cases, has proved very useful in cases of stricture.

ZUSAMMENFASSUNG

Eine Doppelkontrastmethode für die Röntgenuntersuchung der Speiseröhre wird beschrieben. Beim Verzehren von Schaumpulver zusammen mit einer dünnen Bariumemulsion wird in der Speiseröhre Kohlensäure erzeugt; hierdurch wird die Speiseröhre aufgeblasen. Diese Methode, die in rund 100 Fällen ohne jegliche Komplikation benutzt worden ist, hat sich in Fällen mit Stenosen als sehr wertvoll erwiesen.

RÉSUMÉ

L'auteur décrit une méthode de double contraste pour l'examen radiologique de l'oesophage. Une poudre effervescente avalée en même temps qu'une émulsion barytée dégage du gaz carbonique dans l'oesophage qui est ainsi gonflé. Cette méthode qui a été utilisée sans complication dans environ 100 cas s'est montrée très utile dans les cas de rétrécissement.

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SPONTANEOUS REGRESSION OF POLYPS OF THE COLON IN CHILDREN

by

Lars Andrén and *Sture Frieberg*

Polyps of the colon in children are not uncommon. It is recognized that they occur especially in the 4 to 6-year-old age groups (KENNEDY), and then decrease in frequency, only to increase again in adult life between the ages of 20 and 30 (SCARBOROUGH). The reason for this age distribution is quite unknown. The majority of polyps in children have been diagnosed either on account of rectal bleeding, because the growths have been visible outside the anus, or because they have been found in the stools. As children without these symptoms are rarely examined rectoscopically or with a satisfactory roentgen technique, and as the autopsy material for these age groups is very limited, the true frequency of polyps in childhood is particularly difficult to establish. In any case, we have to face the fact that polyps disappear. The only known explanation for this phenomenon, apart from operative removal, would appear to be the spontaneous dropping off of the growths. No case of a polyp showing regression would seem to have been hitherto established but that this may occur, nevertheless, is illustrated by 2 cases in which, at repeated roentgen examinations, a clear regression of polyps of the colon was shown.

The first case was a 5-year-old girl, who, when she came for roentgen examination of the colon, had had blood in the stools for 3 weeks. Rectoscopic examination had not revealed anything pathologic. Roentgenologic investigation, however, performed in accordance with a special elaboration of the double contrast method (ANDRÉN et coll.) showed a polyp, measuring 10 × 10 mm, in the upper part of the rectum, and another,

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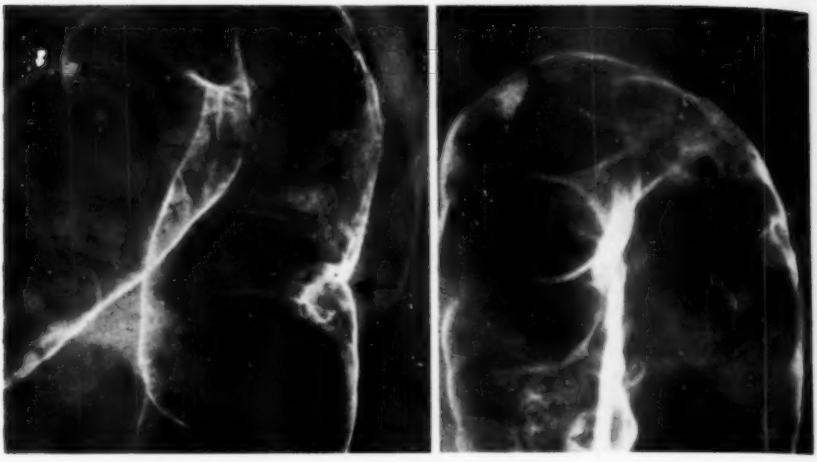

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Fig. 1. Case 1. a) Polyp in descending colon at first investigation. b) Same polyp 20 months later. Obvious regression.

measuring 10 × 8 mm, in the upper part of the descending colon (Fig. 1 a). On control rectoscopy, the polyp in the rectum could still not be established, whereupon the roentgen examination was repeated. The polyps were again shown, and on further rectoscopy the polyp in the rectum was found and removed. It was clearly a benign adenoma (Group I in WESTHUES' classification). Since then the patient has had no blood in the motions. Twenty months later, a control examination of the colon was made. The remaining polyp had clearly decreased in size and then measured 6 × 6 mm (Fig. 1 b) and, six months later, at a further control examination, it had decreased still more, the measurement then being 4 × 3 mm.

The second case was one of a girl aged $5^1/_2$ years who had had bleeding from the rectum for a year; on certain occasions the mother had seen a polyp protruding from the anus. The patient had been sigmoidoscoped repeatedly and on 3 occasions had been examined roentgenologically with contrast enemas without, however, any polyp being detected. On examination with the double contrast method a very mobile polyp, measuring 15 × 10 mm (Fig. 2 a), was found in the sigmoid colon. The polyp could still not be detected by sigmoidoscopy, and signs of bleeding disappeared after the examination. Eighteen months later, on control examination, the polyp had clearly decreased in size; it then measured 7 × 7 mm (Fig. 2 b).

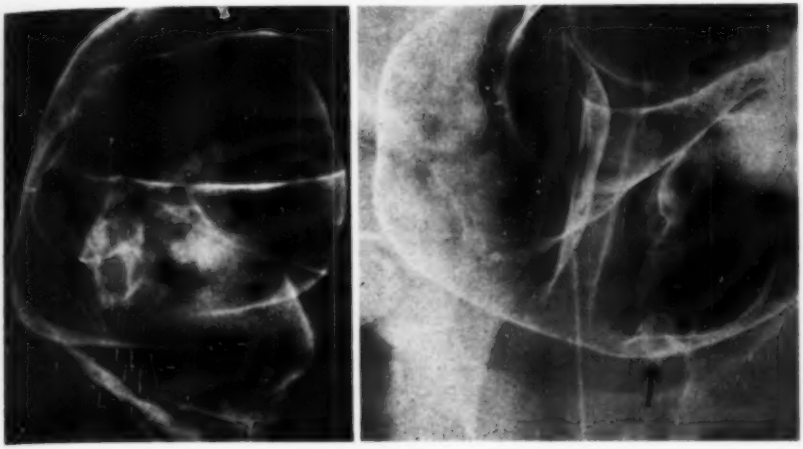

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Fig. 2. Case 2. a) Polyp in sigmoid colon at first investigation. b) Same polyp 18 months later. Obvious regression.

The above two cases show that in polyps of the colon in children spontaneous regression can take place, and that polyps in this situation may be present without symptoms as indeed seems to be the case in the majority of adult cases. The decreasing frequency of polyps in the pubertal years gives rise to the assumption that the majority of these growths in children recede spontaneously. The most common view in the literature would seem to be that polyps — in children not excepted — are potentially malignant and should be removed, even if they lie above the sigmoidoscopic level. The extremely low rate of carcinoma of the colon in children and the fact that polyps may spontaneously drop off or recede indicate that the question of surgical intervention should be treated with restraint.

SUMMARY

Two cases of spontaneous regression of polyps of the colon in children are described. Such regression has not previously been established roentgenologically. It suggests that surgical intervention may be unnecessary.

ZUSAMMENFASSUNG

Zwei Fälle mit spontanem Regress von Dickdarmpolypen im Kindesalter werden beschrieben. Eine derartige Rückbildung ist röntgenologisch bisher noch nicht konstatiert worden. Sie deutet darauf hin, dass chirurgische Intervention nicht notwendig sein mag.

RÉSUMÉ

Les auteurs présentent deux cas de régression spontanée de polypes du colon chez des enfants. C'est la première fois qu'une telle régression est prouvée radiologiquement. Ceci donne à penser que l'intervention chirurgicale ne peut pas être nécessaire.

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ON THE THICKNESS OF THE LAYER IN RECTILINEAR TOMOGRAPHY

by

Olof Willner

Disregarding all the inherent factors producing unsharpness in the roentgenographic process as well as the lost motion and the distortion always present in the tomographic system, an infinitely thin and absolutely sharp central layer may be assumed by the tomographic method. This sharp layer extends into the tomographic blur on both sides. The subjectively perceived thickness of the layer which is represented in the film may be defined as the maximum tomographic blur consistent with adequate visualization. The definition of the tomogram, however, also depends on the factors producing unsharpness in the roentgenographic process as well as the lost motion and the distortion by the tomographic method.

Several authors have determined the thickness of the layer in rectilinear tomography by geometrical calculation. KIEFFER (1939) made this calculation as a geometrical definition of the whole amplitude, taking into consideration the permissible tomographic unsharpness and magnification. Thus he obtained values twice as high as those arrived at by PÖSCHL (1940), VIETEN (1948), WATSON (1951), MALVOISIN (1953) and others, who made the same calculation using half the amplitude. The present writer considers that the thickness of the layer should be calculated as a mean value for a function of half the amplitude, taking into consideration not only the permissible tomographic unsharpness, but the more or less poor contrast produced by the blurred details of the object.

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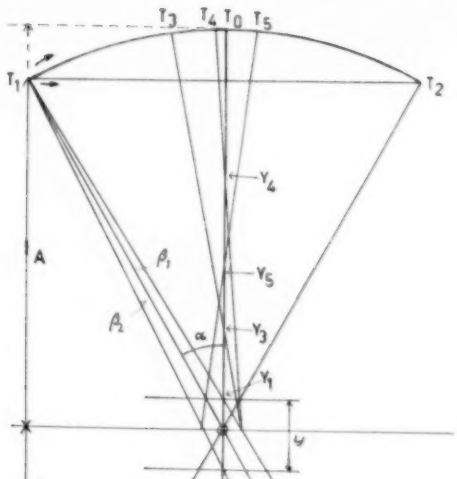

Diagram 1

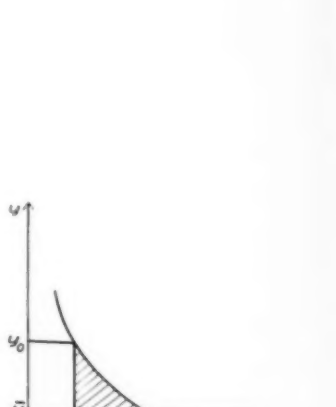

Diagram 2

Diagram 1. The principle of rectilinear tomography either with tube and film moving in parallel planes or along circular arcs. T_1 to T_3 indicate different positions of the tube, and F and G are the end positions of the film. 0 is the pivot axis, A the focus —pivot distance, B the pivot axis—film distance. α is half the amplitude, β_1 and β_2 are the angles for ε which indicates the permissible tomographic blur. y is the minimum thickness of the layer; $0 - Y_1$, $0 - Y_2$, $0 - Y_4$ and $0 - Y_5$ indicate half the minimum thickness of the layer at the respective value for half the amplitude.

Diagram 2. Minimum thickness of layer y as a function of half the amplitude of tube α. y_m represents the minimum thickness of the layer at half the amplitude α_m. y_0 is the double distance from the sharp layer to that detail in the investigated object which at this distance is completely eliminated from the film, with the corresponding angle α. $\bar{y}$ indicates the mean value of the height of the different layers at half the amplitude α_m and considering y_0. The hatched surface shows the portion of the curve utilized at an exposure of amplitude 2 α_m.

Diagram 1 shows a schematic representation of rectilinear tomography with the tube and film performing movements either in parallel planes or along segments of arcs in opposite directions. During the exposure when the tube moves from T_1 to T_2 and the film in the opposite direction from G to F the layer will be thin and approach the minimum thickness y, according to the geometrical construction, in the area of the end position T_1. The layer will then increase in thickness as the angle α decreases and the tube is moved towards T_0. When the tube has passed T_0, which

corresponds to the symmetrical axis of the tomographic system, the thickness of the layer decreases accordingly towards T_2. This is marked by the points Y_1 to Y_5. The distance of these points from the pivot axis 0 constitutes half the thickness of the layer at an amplitude corresponding to twice the respective value for a. A more complete construction has been sketched only at T_1, so as not to obscure the diagram by too many lines.

During the exposure the layer does not increase indefinitely as the tube moves towards the symmetrical axis of the tomographic system. Besides the fact that the object itself is limited, the thickness of the layer is determined by the more or less poor contrast produced in the film by the blurred details of the object. This will result in blurred details of poor contrast in the tomogram, owing to the shorter exposure for these details than for those situated closer to or in the plane in focus. GROSSMANN (1935) discussed these problems and reached the conclusion that when the proportion between the blurred surface and the surface of the object in ordinary radiography is about 10 to 15, the blurring is so effective that the superimposed confusing shadows are completely eliminated in all cases in practical work. Because of great differences in contrast and volume between details in ordinary inhomogeneous objects it is impossible to reach a general figure and to make exact calculations; some idea, however can be obtained empirically in specially selected cases. On lateral tomography with an amplitude of 20° of the skull a small detail in the bone, 3 mm in diameter, was completely blurred out at a distance of 10 mm from the plane in focus. In the same experiment a small lead indicator, 1 mm in diameter, was almost completely blurred out at a distance of 20 mm, and a smaller lead indicator with a diameter of 0.4 mm was completely eliminated at a distance of only 6 mm from the plane in focus. Ilford H. D. screens were used in this experiment, and the films were read in an ordinary light cabinet. Hence, the values are subjective.

The difference in contrast produced in the film by the details of the object situated outside the investigated layer also decreases with increased radiation. In recording a layer of an object where a relatively soft radiation would give the best result, much harder radiation than that optimal for the layer concerned must be used so as to penetrate the whole object. As a result the contrast will be poorer and the layer will appear to be thinner.

In Diagram 1 the permissible tomographic unsharpness is represented by ε. In order to carry out theoretical calculations of the thickness of the layer, a value for ε must be determined. VIETEN accepts a permissible unsharpness of 1.5 mm and KIEFFER 0.3 mm in determining the thickness of the layer. In practice the permissible unsharpness varies considerably according to the degree of contrast and the size of the

different elements in the investigated objects. An exact value for ε is difficult to obtain. PÖSCHL, in his study on tomography in 1940, based his data on a photographic physiologic investigation and set the value for permissible unsharpness at 0.2 mm. Thus, he did not employ the unsharpness that may be tolerated, but a value that represents the limit of what is perceived as sharp or unsharp. This value was calculated at the usual film—object—focus distances. Besides the tomographic blurring there are all those factors causing unsharpness, which exist in conventional radiography, as well as the lost motion in the mechanical tomographic system. The value of 0.2 mm for ε may be used in the calculations only on condition that none of these factors causing unsharpness exceeds this value.

In Diagram 1 the formula

$$y = 2\ \varepsilon \frac{A}{A + B} \cdot \cot \alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

is trigonometrically derived, where y = the thickness of the layer, A = the focus—axis distance, B = the axis—film distance, α = half the amplitude, ε = the permissible tomographic unsharpness. The angles β_1 and β_2 are infinitesimal and may be disregarded when A is so much bigger than ε. Similar calculation is used of the above-mentioned writers except KIEFFER, who uses the whole amplitude. This formula, however, gives the minimum thickness without relevance to the tomographic thickness of the layer represented on the film. This will be readily understood if $\alpha = 90°$, when y will be 0. In experiments with model tomographs with an amplitude of 180° a thin layer is certainly obtained, yet a clear tomogram is produced.

Formula (1) may also be written $y = k \cdot \cot \alpha$ ..... (1 a), where k is a constant depending upon the geometry of the apparatus used and the value set for ε.

From equation (1 a) the depth of focus y will in Diagram 2 be found as a function of half the amplitude of the tube α. y_m is the depth of focus defined by the largest angle of the tube α_m and constitutes the minimum thickness without relevance to the true thickness of the layer. y is the factor that represents the mean value of the thickness of the layer. Because of the aforementioned poor contrast of the image of the details of the object at greater distance from the plane in focus, these are considered to be completely blurred out at a value of $y = y_0$, and, therefore, above this they do not participate in producing an image. The angle for the corresponding y_0 value is set at α_0. The hatched surface indicates

the portion of the curve utilized at an exposure with the amplitude $2 \cdot a_o$. The mean thickness of the layer y is now defined as

$$\bar{y} = k \cdot \frac{\int_{a_o}^{a_m} \cot a \cdot d\, a}{a_m - a_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

or integrated

$$\bar{y} = k \cdot \frac{\left[\log \cdot \sin a \right]_{a_o}^{a_m}}{a_m - a_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

The same argument applies to details situated outside the symmetric axis of the tomographic system, but, of course, within its field of action. Formula (3) contains as a multiplicative constant the factor k which is defined by formulas (1) and (1 a) and the magnitude of which is wholly determined from the geometry of the apparatus used and the value for the permissible unsharpness.

If A = 900 mm, B = 100 mm, and $\varepsilon = 0.2$ mm, k will be 0.36.

In Diagram 3 two curves for the mean thickness of the layer have been calibrated from formula (3). Curve I with $y_o = 20$ mm when a_o will be 1°, and curve II with $y_o = 10$ mm when a_o will be 2°, correspond to a small piece of lead and a small detail of bone respectively, tomographed with exposure factors similar to those used in the lateral projection in routine radiography of the skull, as described in the foregoing. Curve III is the theoretic minimum thickness obtained from formula (1). The measures for y_m and y are inserted divided by the factor k. In this way the comparison between the different curves will be independent of any special geometry of the tomographic apparatus.

To be able to determine the thickness of the layer by mathematical calculations we must, firstly, know the amplitude (2 a), the focus—pivot

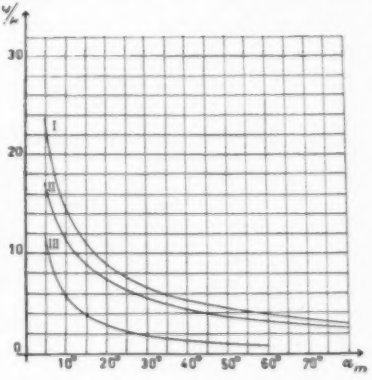

Diagram 3. Curve I — mean thickness of the layer in tomography of a small piece of lead (1 × 1 × 1 mm) with exposure factors corresponding to those used in lateral view of skull. Curve II — the same of a small detail of bone (3 × 3 × 3 mm). Same notation as in Diagram 2. All measures for y are inserted divided by factor k from formula (1 a). y/k is the mean thickness of the layer calibrated from formula (3), and y/k for Curves I and II equals $\bar{y}/k$. Curve III — the minimum thickness obtained from formula (1), and y/k for this curve equals y_m/k.

axis distance and the pivot axis—film distance of the apparatus used (A and B, respectively, in formula (3)). Secondly, we must determine a value for the permissible unsharpness, or, as above, use a value for the photographic physiologic limit of what is perceived as sharp and unsharp (ε in formula (1)). In tomography the degree of unsharpness that is tolerated is usually higher than that accepted in conventional radiography. The value for the thickness of the layer calculated with $\varepsilon = 0.2$ mm will therefore be lower than the thickness of the assessable layer in practical tomographic work. Thirdly, we must empirically determine the distance from the theoretically sharp layer at which a detail in the object is completely eliminated from the film at the given factors of exposure, and from this distance estimate the corresponding angle designated as α_0 in formula (3). Thus, the calculation of the thickness of the layer must be made for a selected detail in the object (two adjacent elements of the object) at the given exposure factors.

The calculation of the thickness of the layer by rectilinear tomography is of theoretical interest. It is also of practical value *e. g.* in determining the intervals between the tomographic sections of the whole object to be examined and for localizing foreign bodies by tomography.

SUMMARY

The thickness of the layer in rectilinear tomography is calculated as a mean value of half the amplitude, taking into consideration the magnification, the permissible tomographic blur, and the contrast and size of the elements of the object.

ZUSAMMENFASSUNG

Die Schichtdicke bei der geradlinigen Tomographie wird als ein Mittelwert der halben Amplitude berechnet. Hierbei werden die Vergrösserung, die zulässliche tomographische Unschärfe sowie der Kontrast und die Grösse der Elemente des Objektes berücksichtigt.

RÉSUMÉ

L'épaisseur de la couche de coupe en tomographie rectiligne est calculée en fonction de la valeur moyenne de la moitié de l'amplitude, et en tenant compte de l'agrandissement, du flou tomographique acceptable et du contraste et des dimensions des éléments de l'objet.

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VENOUS COMMUNICATIONS BETWEEN THE CARDIAC VEINS AND THE LARGE VENOUS TRUNKS IN THE SUPERIOR PART OF THE MEDIASTINUM

by

Carl-Olof Ovenfors

In a case in which selective angiocardiography was recently performed in order to visualize valvular pulmonary stenosis, the catheter tip was repelled at the beginning of the injection of the contrast medium from the right ventricle into the right atrium and thence into the coronary sinus. This resulted in filling not only of all the cardiac veins, but also of a vascular network in the supero-anterior part of the mediastinum, which evidently communicated with them. As far as I am aware, a mediastinal vascular system of this kind has not earlier been described in man. Consequently, an account of the observations and of the roentgenologico-anatomic studies on autopsy material arising from them seems to be warranted.

The patient was a 10-year-old boy. Apart from rapidly transient extrasystoles during the injection of the contrast medium, there were no complications during angiocardiography.

As seen in Fig. 1, retrograde filling of a richly branched vascular plexus in the anterior part of the mediastinum was obtained during the end of the injection. It extends in front of the pulmonary artery and the aorta. There is seen to be a communication with the cardiac veins. In the upper part of the vascular network, a few larger vessels are visible; they run towards the left innominate vein. No extravasal flow of contrast

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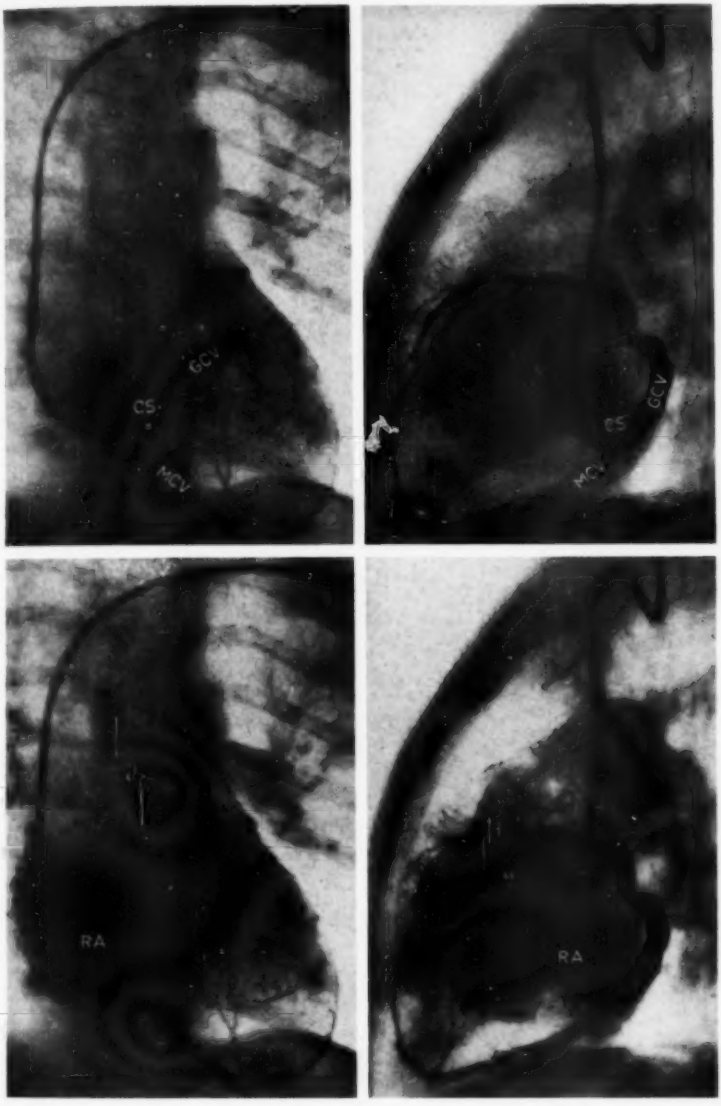


Fig. 1. Angiocardiography. *Top:* at beginning of injection; *Below:* 1/3 sec later. Catheter tip repelled into opening of coronary sinus. Filling of cardiac veins and network of smaller veins in superior part of mediastinum, surrounding pulmonary artery. From this network, filling of some larger branches, running towards the horizontal course of catheter, *i. e.* to left innominate vein (LIV). CS — coronary sinus; GCV and MCV — great and middle cardiac veins; RA — right atrium.

Fig. 2

Fig. 2. Autopsy experiment. Heart *in situ*, moderately rotated to left. About 20 ml contrast medium injected through opening of coronary sinus. Great (GCV), middle (MCV) and small (SCV) cardiac veins visualized.

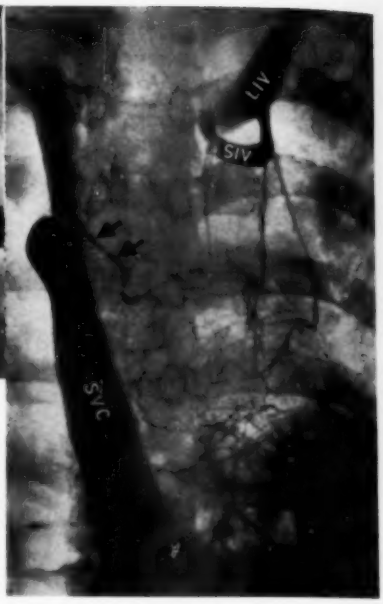


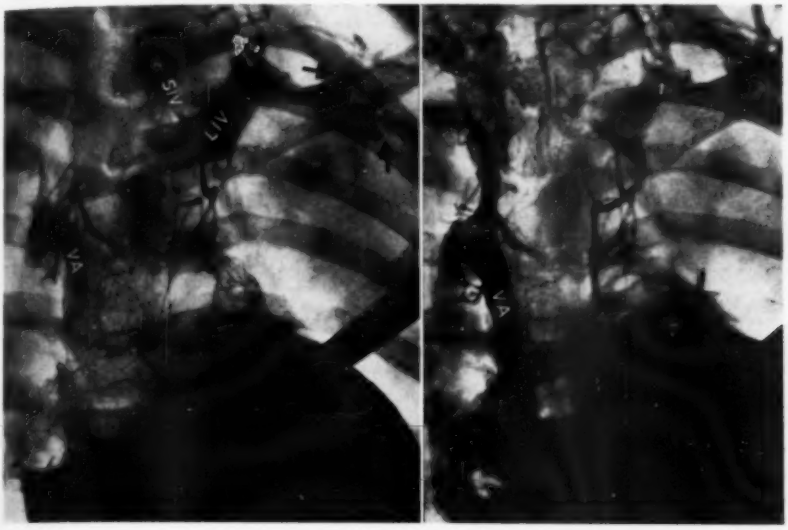
Fig. 3

Fig. 3. Autopsy experiment. Heart *in situ*. About 100 ml contrast medium injected. Filling of network of vessels in mediastinum, communicating with superior intercostal vein on left side. Another communication runs to superior vena cava, in region of opening of azygos vein (arrows). LIV — left innominate vein; SIV — superior intercostal vein; SVS — superior vena cava.

medium indicative of rupture of a vessel can be seen, either in the coronary sinus system or in the borderline zone between it and the mediastinal vascular plexus.

With a view to obtaining further information on the occurrence and roentgenologic anatomy of the vascular network, contrast medium (Umbradil 70 %) was injected into the coronary sinus in an unselected series of 11 autopsy cases, aged from 16 to 64 years. There were no signs of heart disease in any of the cases. The tricuspid orifice and the great veins were plugged with tampons. Exposures were made in the frontal and lateral projections in half of the material, and only in the frontal in the other half. Nine injections were technically successful.

On injection of a small quantity of contrast medium, only the cardiac veins were filled (Fig. 2). When the quantity was increased somewhat, a mediastinal vascular network of the same appearance and localization as that in Fig. 1 was filled in every case. When a still larger quantity of contrast medium was injected, a number of anastomoses became filled;



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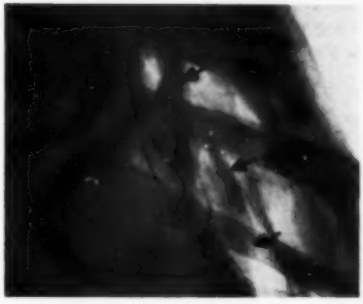

c

Fig. 4. Autopsy experiment. Heart *in situ*. After injection of about 100 ml (a and c) and about 150 ml (b) contrast medium into coronary sinus. Visualization of mediastinal vessels with communication to left innominate vein via left superior intercostal vein, and to superior vena cava. Retrograde filling of neck veins and left axillary vein, in which the valves are seen (arrows in a). In lateral view (c), the mediastinal network is situated just below the pericardium (arrows). LIV — left innominate vein; SIV — superior intercostal vein; VA — azygos vein.

some communicated with the left innominate vein via the first intercostal vein on the left side, and others with the superior vena cava close to the opening of the azygos vein (Figs. 3 and 4). No extravasation of contrast medium was visible.

It was thus possible in these investigations to show the presence of richly branched anastomoses between the cardiac veins and the large venous trunks in the superior part of the mediastinum. The lack of extravasation of contrast medium, both in the autopsy cases and in the patient in which the observation was first made, indicates that the communications are direct, and that the vascular network is therefore composed of

veins. The plexus cannot be demonstrated on filling of the large veins in the superior part of the mediastinum, but can be visualized on forced retrograde injection of contrast medium through the cardiac veins. Consequently, it is also probable that the flow through it is inappreciable under normal conditions.

Extracardiac vascular communications of a similar nature have been shown in the dog, for example. (GREGG and HIPLEY) These anastomoses could be considerably better visualized when the cardiac veins were ligated. It therefore seems plausible to infer that, in man as well, the anterior mediastinal vascular plexus can serve as a collateral circulation in the presence of an impediment to emptying of the cardiac veins.

SUMMARY

During selective angiocardiography, recoiling of the catheter tip resulted in visualization of a mediastinal vascular network, communicating with the coronary sinus system. Its existence was confirmed in an unselected series of nine autopsy cases.

ZUSAMMENFASSUNG

Bei einer selektiven Angiocardiographie erzeugte das Zurückgleiten der Katheterspitze die Darstellung eines mediastinalen Gefässnetzes, welches mit dem Gefässystem des Sinus coronarius kommunizierte. Die Existenz dieser Verbindung wurde in 9 nicht speziell ausgewählten Obduktionsfällen bestätigt.

RÉSUMÉ

Le recul de l'extrémité du cathéter au cours de l'angiocardiographie sélective a eu pour conséquence la visualisation d'un réseau vasculaire médiastinal, communiquant avec le système du sinus coronaire. Son existence a été confirmée sur une série non sélectionnée de neuf autopsies.

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MALIGNANT LYMPHOMA OF THE GASTROINTESTINAL TRACT: ROENTGENOGRAPHIC CONSIDERATIONS

by

C. C. Wang and *James A. Petersen*

The medical literature concerning malignant lymphoma is voluminous. The condition has been discussed repeatedly from the standpoints of etiology, histopathology, classification, diagnosis, therapy, involvement of different parts of the body, and innumerable other approaches (7, 10, 13, 16, 19). The disease is characterized by neoplastic proliferation of the lymphoid and reticular tissues of the body, and its course is considered uniformly fatal, but a few cases of apparent cure either from early excision or by roentgen therapy of the primary focus have been observed. Any portion of the body may be involved either by a localized or by a generalized disseminated process. Involvement of the gastrointestinal tract by lymphoma is not uncommon. Approximately ten per cent of all the lymphoma patients admitted to a general hospital are affected (unpublished material).

The present report covers a review of the roentgenograms of 165 patients seen at the Massachusetts General Hospital in the past twenty years, in whom lymphomatous involvement of the esophagus, stomach, or intestine has been proved histologically by operation or post mortem examination. The histologic classification of malignant lymphoma as suggested by GALL and MALLORY (7) has been followed. For simplicity of presentation the term "localized lymphoma" is used to indicate that at the time of initial examination and/or at operation the tumor was apparently confined to one structure; 'generalized lymphoma' is employed when the involvement of the gastrointestinal tract was a part of a known process already disseminated. In 89 of the entire group the disease was considered to arise primarily in the gastrointestinal tract without evidence

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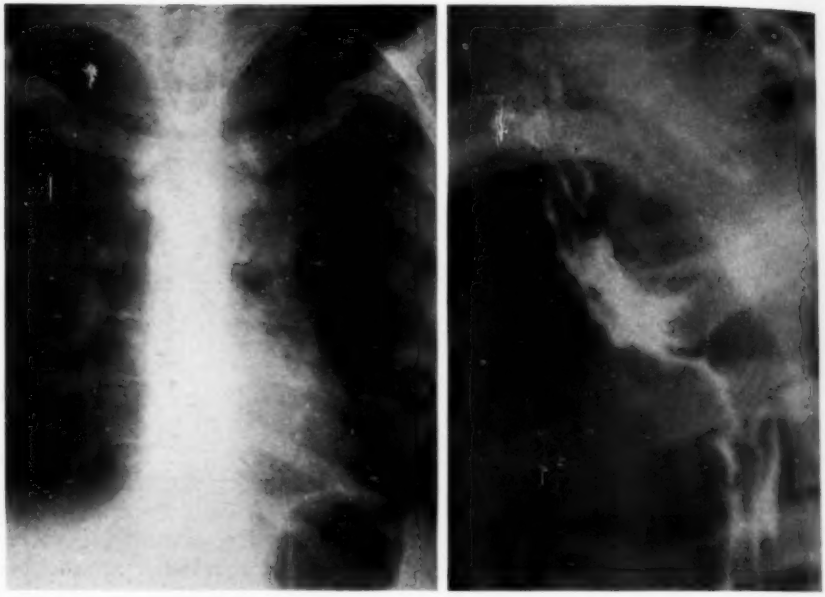

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Fig. 1. Hodgkin's lymphoma of the esophagus and mediastinum. a) Mediastinal lymphadenopathy. b) Ulcerating lesion in the upper third of the esophagus. The trachea was considerably narrowed.

of distant metastases, and in 76 the neoplasm was known to be a part of a generalized process. Roentgenograms were available for study in 66 cases; 4 of the esophageal group, 48 of the gastric, 12 of the small bowel, and 2 of the large bowel. This material forms the basis of the present investigation.

Lymphoma of the esophagus. Malignant lymphoma of the esophagus is rare. Of the entire group there were only nine patients (5 per cent) in whom this diagnosis was made; of these, roentgenograms were available in four. In two patients, the tumor was apparently confined to the esophagus; one in the middle third and the other in the upper third, both showing a large ulcerating filling defect. In the other two cases the lymphomatous involvement was considered a part of a generalized disease. In one of these an intraluminal cauliflower-like defect in the esophagus was associated with mediastinal lymphadenopathy (Fig. 1); in the other, a solitary lymphomatous nodule was seen in the lower esophagus with ulceration of the overlying mucosa. There was no definite roentgenologic pattern distinguishing localized from generalized lymphoma.

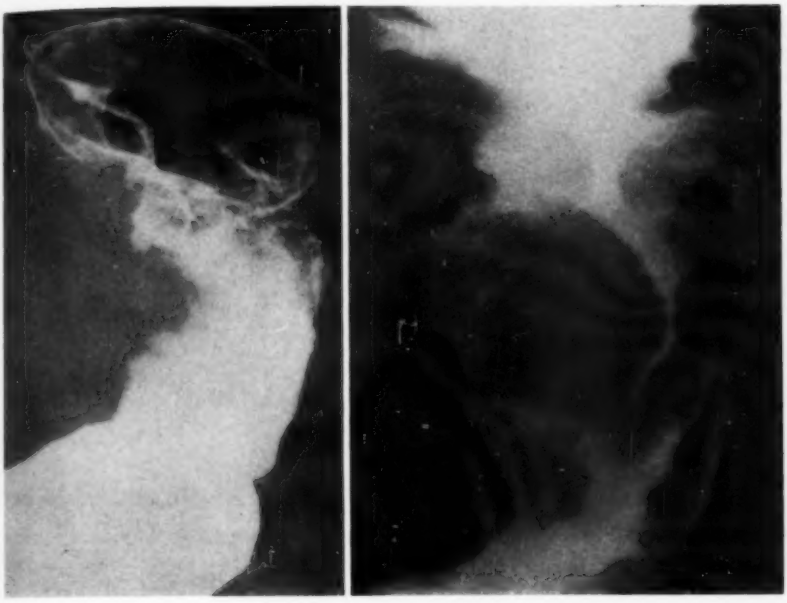

Fig. 2. Reticulum cell sarcoma of the stomach. Polypoid filling defects along the lesser curvature in the proximal half of the stomach.

Lymphoma of the stomach. Malignant lymphoma of the gastrointestinal tract is probably most common in the stomach. A great deal on the subject has been published, the majority of authors concluding that the process often cannot be differentiated from carcinoma. Certain findings, however, were considered strongly suggestive of the disease: 1) giant rugal folds involving a large portion of the stomach; 2) extensive involvement but with little impairment of peristalsis; 3) multiple gastric ulcers; 4) in a young patient, a large gastric ulcer and/or a palpable tumor mass (2, 3, 4, 9, 15).

Of the group of 165 cases, 82 patients (50 per cent) had lymphoma of the stomach, and of these, 57 were considered localized and 25 generalized; in 48 cases, roentgenograms were available for study. The lesions varied considerably in appearance and were most often observed in the distal portion of the stomach. For ease of description an arbitrary division into five categories could be made, but individual cases at times evidenced complicated mixed patterns.

1. *Intraluminal fungating lesions* (Fig. 2). Malignant lymphoma frequently presented as large, irregular, fungating lesions which were not

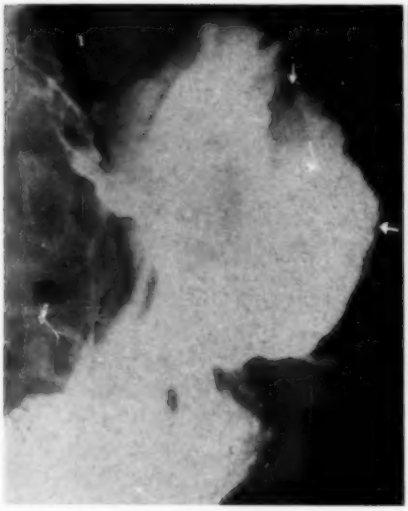

Fig. 3. Large ulcer in reticulum cell sarcoma of the stomach. A large ulcer crater measuring approximately 5 cm in diameter with fairly smooth edges in the proximal portion of the greater curvature of the stomach. A sinus tract extending laterally within the mass.

Fig. 4. Nodular ulcerating lesions in Hodgkin's sarcoma of the stomach. The gastrointestinal series revealed the gastric folds diffusely thickened throughout. Umbilicated, doughnut-like nodular lesions measuring approximately 1.5 cm in size were noted in the proximal stomach.

only extensive but often showed severe ulceration; occasionally the entire stomach was involved. Eighteen of the group fell into this category, of which 16 were localized lesions and two were generalized. When the gastric antrum was involved, the process at times extended into the base of the duodenal bulb; the stomach was moderately stiffened but peristaltic waves were not completely absent. The outstanding feature was the extensiveness of the disease in comparison with the minor clinical symptoms. In only one case was the tumor associated with pyloric obstruction.

2. *Large ulcer* (Fig. 3). Lymphoma of the stomach producing a large crater as the predominating finding was observed in 12 patients. The border and base of the ulcer tended to be ragged and associated with irregular soft tissue masses. At times sinus tract formation was seen. The ulcer was located in various portions of the stomach and often was accompanied by thickening and widening of the gastric folds.

3. *Nodular, ulcerative lesions* (Fig. 4). Three patients exhibited smooth nodular lesions simulating ulcerated intramural extramucosal

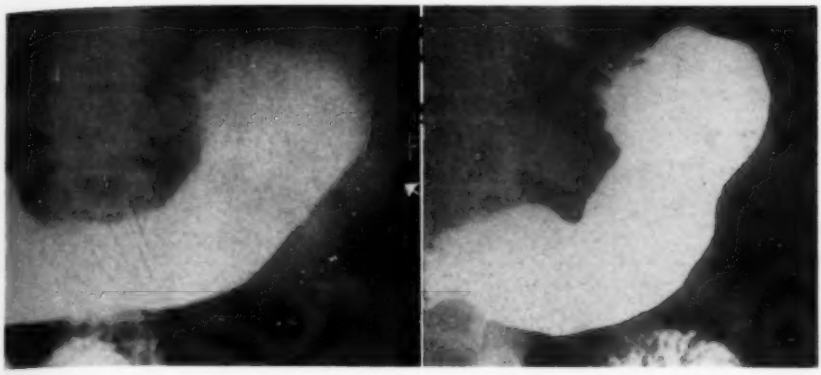

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Fig. 5. a) Scirrhous lymphocytic lymphoma. Thickened gastric wall along the greater curvature of the stomach. The proximal two-thirds of the stomach appeared rigid. The gastric lumen was otherwise fairly smooth and not narrowed. b) One and a half years later, after external radiation. The thickening of the gastric wall has diminished. Peristaltic waves have returned.

tumors. When the central ulceration was filled with contrast medium and separated from the surrounding portions of the stomach by the heaped up tumor tissue, a well-defined doughnut-like picture was produced which varied from 2 to 3 cm in size. The nodule was sometimes solitary, at others multiple with relatively normal intervening mucosa.

4. *Diffuse enlargement of the gastric folds.* Eleven patients showed extensive lymphomatous involvement of the stomach with great hypertrophy of the rugae. Occasionally superficial ulcerations along the curvatures were seen and the peristaltic waves though generally present were sluggish. The enlarged folds were distorted and tended to retain a similar pattern in subsequent examinations. The disease process was at times localized, at others involved the entire stomach. The duodenum was generally normal.

5. *Scirrhous type lesions* (Fig. 5). In four patients extensive intramural infiltration of the stomach produced marked thickening and stiffening of the gastric walls with absence of peristaltic waves and with or without narrowing of the gastric lumen.

Lymphoma of the small bowel. Lymphoma of the small bowel has been recognized with increasing frequency in recent years (12, 14, 18). In the 59 cases (36 per cent) of the present series, 26 were localized, and 33 generalized lymphoma. Roentgenograms, available in 12 cases, exhibited certain manifestations as follows.

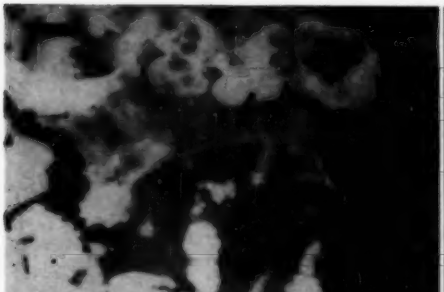

Fig. 6. Multiple ulcerating lymphomatous lesions in the lower ileum with no intestinal obstruction.

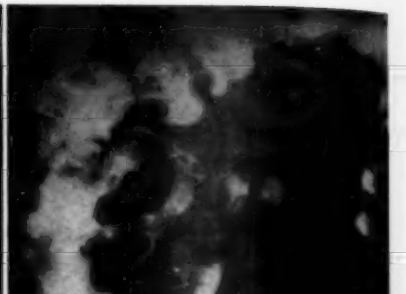

Fig. 7. Large soft tissue mass in Hodgkin's sarcoma of the small intestine. Irregular lumen and loss of the normal mucosal pattern but no significant small bowel obstruction.

1. *Multiple ulcerating lesions* (Fig. 6). In six patients lymphoma of the small bowel presented multiple ulcerating lesions with relatively normal intervening mucosa. The tumors varied in length producing some widening of the intestinal lumen. DUNDON (5) considered this to be a typical expression of lymphosarcoma in the small bowel. SWENSON (17) reported a case of similar appearance due to multiple plasmacytomas.

2. *Large soft tissue mass* (Fig. 7). Three patients with lymphoma of the small bowel manifested a large soft tissue mass in the abdomen measuring on the conventional films up to 10 cm in diameter. Irregular air-containing channels traversed the soft tissue pattern. On barium study these channels were shown to be the lumen of the involved bowel, fixed and slightly dilated, with the mucosa destroyed or replaced by tumor. This finding of dilatation rather than stenosis of the lumen at the site of the tumor was first related to lymphosarcoma by ZIMMER (20) in 1923, and subsequently has been emphasized by others (8, 11, 5).

3. *Nodular lesions.* In one instance the lymphomatous process was composed of several rounded nodular filling defects measuring 1 to 2 cm in size in the terminal ileum without evidence of intestinal obstruction. The intervening mucosa was apparently normal.

4. *Transient intussusception.* In one case the lymphoma produced transient small bowel intussusception with obstruction.

5. *'Deficiency pattern'* (Fig. 8). A bizarre mucosal appearance mimicking so-called deficiency pattern was seen in a patient in whom there was extensive lymphomatous infiltration of the entire small intestine. The appearance was produced by multiple tiny conglomerations of tumors — sizes varying from 0.5 to 1.5 cm, in the intestinal wall. Nowhere was a normal mucosal relief demonstrated. The transit time through the small bowel was normal. GOLDEN (8) described two cases in the literature with similar roentgen appearance of small bowel lymphoma associated clinically with signs and symptoms of sprue.

Fig. 8. Deficiency pattern in Hodgkin's sarcoma of the small bowel. A diffuse lesion involving the jejunum and the ileum. Prominence of the mucosal folds with an extremely bizarre pattern. Transit time through the small bowel normal.

Lymphoma of the large bowel. Malignant lymphoma, found in any portion of the colon (18), is as rare as that of the esophagus in comparison with involvement of the other parts of the gastrointestinal tract. Out of the entire group there were 15 cases (9 per cent) in whom the diagnosis was made. Of these only two patients had roentgenograms for study; in both cases the lesions were located in the proximal colon. In one case the tumor was encountered in the cecum showing a rather smooth filling defect without ulceration; and in the other an annular lesion was located in the ascending colon with no intestinal obstruction. In neither instance could the lymphoma be differentiated from carcinoma. No cases in which malignant lymphoma arose in the appendix were encountered.

So-called benign lymphoma of the rectum is an entirely different disease entity and does not follow the usual course of malignant lymphoma. It has not been considered in this study.

The spleen. It is interesting to note that out of 66 patients with lymphoma of the gastrointestinal tract, 50 showed no roentgenologic

evidence of splenomegaly; of the 16 who had splenic enlargement of slight to moderate degree, six patients were considered to have localized disease and the remainder generalized disseminated lymphoma. It is evident that splenic enlargement is not a reliable diagnostic aid in differentiating lymphoma from other neoplastic disease in the gastrointestinal tract.

Discussion and differential diagnosis

Malignant lymphoma of the gastrointestinal tract presents differing radiographic manifestations and mimicks a variety of organic diseases. It is probable that by roentgenologic examination alone differentiation between carcinoma and solitary lymphoma of the esophagus or of the colon is unlikely. In the stomach, however, the diagnosis may be suggested. Extensiveness of a lesion associated with a paucity of clinical complaints may help in distinguishing between intraluminal fungating lymphoma and carcinoma. Huge craters in gastric lymphoma may be confused with peptic ulcer or ulcerating carcinoma. Extreme widening of the gastric folds due to lymphoma often masquerades as severe gastritis, mucosal hypertrophy and superficial spread of carcinoma, and their differentiation is extremely difficult without a tissue biopsy. Stiffening and thickening of the gastric wall may be due to scirrhous carcinoma as well as lymphoma although in the latter the lumen may not be significantly narrowed. Ulcerative nodular lesions resemble the appearance of spindle cell tumors.

Lymphoma of the small bowel presents interesting features. Multiple ulcerating lesions with relatively normal intervening mucosa without intestinal obstruction are a fairly frequent finding which may be considered characteristic of lymphoma. A large soft tissue mass associated with destruction of the mucosa but without narrowing of the intestinal lumen, may resemble intestinal leiomyosarcoma or retroperitoneal fibrosarcoma extending into the bowel (6). Nodular lymphomatous lesions simulate polypi and their differentiation may be difficult. Transient small bowel intussusception caused by lymphoma cannot be distinguished from that due to other causes. When severe lymphoma in the small intestine presents a 'deficiency pattern', it may be confused with a variety of diseases, and the roentgenologic differentiation may not be feasible without other clinical clues.

SUMMARY

A roentgenologic study of 66 patients with proved malignant lymphoma involving the esophagus, stomach, small and large intestine has been presented. The lesions ex-

hibited a variety of roentgenologic patterns, mimicking a number of benign and malignant conditions. It is concluded that the roentgen diagnosis of malignant lymphoma of the gastrointestinal tract can seldom be made without a tissue biopsy, particularly in those patients with primary manifestations of the disease. However, when the involvement of the gastrointestinal tract is a part of a longstanding generalized process the diagnosis may be more readily recognized.

ZUSAMMENFASSUNG

Eine röntgenologische Studie an 66 Patienten mit histologisch verifiierten malignen Lymphomen, die den Ösophagus, den Ventrikel und den Dickdarm infiltrieren, wird vorgelegt. Die Erkrankungen zeigten eine Mannigfaltigkeit des röntgenologischen Aussehens; sie waren einer Reihe benigner und maligner Zustände verwechselnd ähnlich. Es wird konkludiert, dass die Röntgendiagnose maligner Lymphome des Magen-Darmkanales selten ohne Probeexcision gestellt werden kann, besonders bei Patienten mit primären Manifestationen der Krankheit. Wenn jedoch die Infiltration des gastrointestinalen Gebietes ein Teil eines langdauernden generalisierten Prozesses darstellt, kann die Diagnose leichter gestellt werden.

RÉSUMÉ

L'auteur présente une étude radiologique de 66 malades atteints de lymphome malin vérifié, intéressant l'oesophage, l'estomac, l'intestin grêle et le colon. Ces lésions revêtaient des aspects radiologiques variés, simulant un certain nombre d'affections bénignes et malignes. L'auteur conclut qu'il est rarement possible de faire le diagnostic radiologique de lymphome malin du tube digestif sans une biopsie, en particulier chez les malades où les premières manifestations de la maladie sont digestives. Cependant, quand l'atteinte du tube digestif n'est qu'une partie d'un processus généralisé chronique, le diagnostic peut être plus facilement posé.

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ARTERIAL SUPPLY TO THE HEAD OF THE FEMUR

An arteriographic study in vivo of lesions attending fracture of the femoral neck

by

Herbert Müssbichler

The arterial supply to the head of the femur has hitherto been studied almost exclusively in anatomic specimens and a report of the examination of these vessels *in vivo*, particularly in conditions which may give rise to aseptic necrosis of the femoral head, may consequently be of interest.

Aseptic necrosis complicates medial fractures of the neck of the femur in approximately 30 per cent of cases (LINDQUIST 1951, BÖHLER 1954, Nyström 1954) and may to some extent be dependent on the speed of healing of the fracture (SHERMAN & PHEMISTER 1947).

Adduction fractures of the neck of the femur are the most unfavourable as regards prognosis since the large nutritive vessels on the lateral aspect of the joint capsule are then particularly exposed to damage (TRUETA et coll. 1953). The cause of aseptic necrosis is thought generally to be a traumatic disturbance in the blood supply to the head of the femur.

Aseptic necrosis is associated not only with injury, but may result also from caisson disease, embolism, thrombosis and obliterating diseases (PHEMISTER 1949). Of these, caisson disease is the condition which has been most widely studied in this connection (WALKER 1940; RETTIG 1951; MC CALLUM 1954; and others). Aseptic necrosis, which is most frequently localized to the head of the femur, the head of the humerus, and the tibia, is believed to be brought about by nitrogen emboli resulting from decompression in persons working in caissons.

REICH et coll. (1935) described 6 cases of sickle-cell and Cooley's anaemia, in 3 of which aseptic necrosis of the femoral head developed. All stages of necrosis are found in Perthes' disease, and vascular lesions cannot be ruled out as a possible causative factor (BRAILSFORD 1945).

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Arterial supply to the femoral head. The gross anatomy of the blood supply to this area has been described by LANZ & WACHSMUTH (1938), HOWE & SCHWARTZ (1950), and others.

The nutrition of the femoral head is furnished by the medial circumflex artery of the thigh and the artery of the ligamentum teres. *The medial circumflex artery* springs from the deep femoral artery, traverses the dorsal aspect of the femoral neck and continues along its lateral aspect in the substance of the articular capsule and the periosteum up to the metaphyseal and epiphyseal areas of the head. It is this so-called 'upper capsular or synovial artery' which is believed to convey the bulk of the blood to the head of the femur (NUSSBAUM 1926; WOLCOTT 1943; TUCKER 1949; HOWE & SCHWARTZ 1950). This artery with its branches has been variously termed: posterior superior retinacular artery (TUCKER); ramus nutritius colli et capitis (NUSSBAUM); superior metaphyseal and lateral epiphyseal artery (TRUETA); and superior capital branch (HOWE & SCHWARTZ). According to TRUETA, the upper capsular artery and its branches supply two-thirds to four-fifths of the epiphysis of the femoral head, the remainder of the epiphyseal supply being furnished by the artery of the ligamentum teres. At the level of the medial margin of the femoral neck, the medial circumflex artery gives off the lower capsular branch which runs in the substance of the distal medial portions of the capsule and the periosteum, supplying the medial portion of the metaphysis of the head. This branch is also termed the inferior synovial artery by many authors, and the 'inferior metaphyseal artery' by TRUETA. In 44 anatomic specimens, TUCKER (1949) found the mean diameter of the upper capsular branch to be 0.839 mm and the lower capsular branch 0.410 mm.

The artery of the ligamentum teres. From the obturator artery, or occasionally from the medial circumflex artery, an acetabular branch arises and gives off an artery which runs within the ligamentum teres to the pit in the femoral head. The artery of the ligamentum teres enters this pit; it is also known as the arteria foveolaris and has been described by many authors (NUSSBAUM 1926; WOLCOTT 1943; TUCKER 1949; TRUETA et coll. 1953, and others).

CHANDLER & KREUSCHER (1932) studied 114 anatomic specimens, in 4 of which the ligamentum teres was relatively avascular, in 8 a large number of small vessels were present, in 16 the arteries were sclerotic and partially or wholly obliterated, and in 86 there were arteries with a mean diameter of 0.2 to 1.5 mm. TUCKER (1949), who carried out an histologic examination of 20 anatomic specimens from adults, found the average diameter of the ligamentum teres artery to be 0.328 mm, or less than half that of the upper capsular artery (see above). This author reports the artery of the ligamentum teres to be present in 33 per cent

of infants and children and in 70 per cent of adults, while the upper capsular branch is invariably present at all ages. WOLCOTT (1943) found the ligamentum teres artery to be present in 80 per cent of his specimens. TRUETA et coll. (1953), who studied anatomic specimens from adults micro-roentgenographically stated that the artery of the ligamentum teres supplies only one third to one fifth of the epiphysis of the head of the femur. There is a free anastomosis between the epiphyseal and metaphyseal branches which does not, however, function until the epiphyseal cartilage is fully ossified (TUCKER 1949). In infants and children, TUCKER and other authors believed that the artery of the ligamentum teres supplies the ossification centre of the femoral head, while WOLCOTT, and ALLENDE (1951) expressed the view that the femoral head is not supplied by the ligamentum teres artery, but solely by the capsular arteries.

The findings of STEWART's (1933), KISTLER's (1936), and WOLCOTT's (1943) animal experiments are in agreement with TRUETA's and others' observations on the incidence, distribution, and smaller diameter of the ligamentum teres artery, as compared with the capsular arteries. Division of the ligamentum teres in dogs and rabbits leads to no great structural changes in the femoral head. On the other hand, KISTLER reports that ligation of the neck of the femur (arresting the circulation in the capsular arteries) in 4-day-old rabbits produces complete necrosis and separation of the femoral head. In adult rabbits, only dilatation of the ligamentum teres artery and hyperaemia in the acetabulum results.

The changes in the femoral head were more marked if, in addition to ligature of the femoral neck, the ligamentum teres vessels were cut. KISTLER also studied experimental fractures in rabbits, and came to the following conclusion: "The blood supply through the ligamentum teres in adult rabbits may not be sufficient to prevent complete necrosis of the fractured segment, but certainly it is important as a potential source when collateral circulation is needed." NORDENSSON (1938) found vessels to be present in the ligamentum teres in the majority of 129 specimens. He also pointed out that in medial fractures of the femoral neck, the ligamentum teres vessels were wider than in the normal hip. NORDENSSON interprets this as a mechanism of adaptation to an abnormal blood circulation (resulting from the medial fracture); his findings agree in some measure with KISTLER's studies of the rabbit (ligature of the femoral neck periosteum leading to hyperaemia in the acetabulum and the ligamentum teres artery).

Anastomoses. OLOVSON (1941) studied the anastomoses of the adult hip roentgenographically in specimens. He found the largest anastomoses between the external iliac and the femoral arteries to be via the obturator

and medial circumflex arteries. In 53 of 107 cases this communication was contrast-filled on gross examination. After ligature of the external iliac or the femoral artery in experimental animals, new anastomoses formed between the two systems; these were contrast-filled as early as 6 days after ligation of the artery. OLOVSON's studies have clarified the communications between the obturator and medial circumflex arteries, which together furnish the entire supply of blood to the femoral head; they also show the speed with which new communications develop in the presence of an obstruction to the blood flow.

To sum up the results of the anatomic, histologic, and experimental studies, we may state that the lower, and particularly the upper, capsular branches are the most important sources of supply to the femoral head. The ligamentum teres artery, which may be wholly absent or obliterated, plays a smaller part but may in some measure compensate for a disturbance of the circulation in the capsular vessels.

On arteriography of the femoral artery in 10 patients with medial or intertrochanteric fractures of the femur, ROOK (1953), obtained filling of larger vessels, such as the femoral, deep femoral, and circumflex arteries. He found the blood supply to be 'excellent' in 2 patients, 'definitely inadequate' in 4, 'limited' in 3, and 'moderate to poor' in 1 patient. ROOK interprets the arteriograms as follows: 'It seems reasonable that if the vascular supply including the femoral, profunda, and circumflex arteries and their branches, is thin and tortuous, or in part absent, it is probable that the other units are equally disturbed or deficient.'

Thus, ROOK bases his conclusions solely on the general contrast-filling of the deep femoral and circumflex arteries on the involved side. Arteriography was not performed on the sound side; consequently, no evidence based on comparison of the two sides could be adduced to confirm the pathologic nature of his findings.

HULT (1953) studied the nutrition of the head of the femur *in vivo* with particular regard to the prognosis for necrosis of the femoral head resulting from fractures of the femoral neck. He investigated the veins by injection of contrast material into the spongy substance of the femoral head. This was performed at operation by means of a special cannula introduced into the bone. After injection of 3 to 5 ml Umbradil 50 %, two frontal views and one lateral view were obtained. HULT terms the result 'positive' if the synovial veins or the ligamentum teres veins, or both systems, were contrast-filled, and concludes that the corresponding arteries were also intact — implying a favourable prognosis for the healing of the fracture and the prevention of necrosis of the femoral head. When the results are 'negative', i. e. no veins are visualized, the opposite

may apply in some measure as regards the state of the arteries and prognosis.

HULT's phlebographic findings are of great interest, but the author does not specify which veins and arteries he considers most important for prognosis as regards necrosis of the head. One has the impression that even in normal subjects it is not possible to predict which veins will be contrast-filled, since it is almost impossible to achieve exactly the same position of the cannula in the bone from one case to another — as emerges in HULT's illustrations. The fact that no phlebograms of the contralateral side are available for comparison detracts from the value of the method for prognosis.

Present Investigation

Arteriography of specimens of the hip

To enable study of the vascular anatomy of the femoral head, contrast medium was injected into a number of specimens. The contrast material, white lead pulp, was injected into the external iliac artery with a syringe under moderate manual pressure.

Fig. 1 illustrates the gross vascular anatomy of the head of the femur. For the portion of the medial circumflex artery distal to the origin of the main branches to the intertrochanteric notch, the term 'posterior collum branch' is used. At the level of the intertrochanteric notch this latter gives off the superior synovial vessels, and immediately after its origin, the inferior synovial vessels. The grains of lead were certainly too coarse to penetrate the microscopic anastomoses. Nor was it the author's intention to visualize these communications since the literature already contains sufficient material on the subject.

It should be noted that the contrast medium in the artery of the ligamentum teres was in the main conveyed by an acetabular branch springing from the medial circumflex artery.

Arteriography in vivo

Methods. In the majority of cases, the femoral artery was punctured percutaneously at the level of the inguinal ligament, and 15 to 20 ml Dijodone 50 % injected. In some instances, the deep femoral artery was punctured instead of the femoral artery to ascertain whether or not the density of contrast medium in the medial circumflex artery and its branches was affected; no change was noted.

In a few cases, a catheter was introduced into the artery on lines described by SELDINGER (1953) for a distance of 18 cm in order to outline also the vessels of the opposite hip.

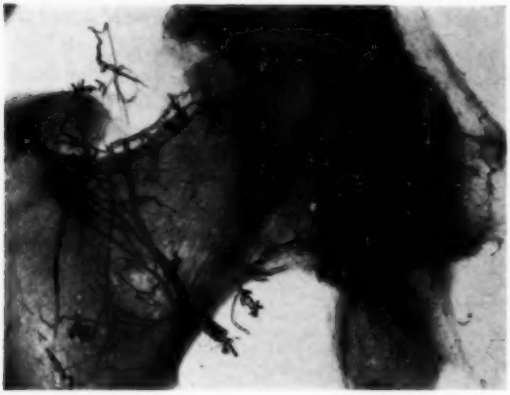

Fig. 1. Arteriography of specimen of hip. Post. collum branch (↓). Superior synovial arteries (↕). Inf. synovial artery (↕). Artery of the ligamentum teres (↓). Acetabular branch of the med. circumflex artery (↕).

The filling of the arteries was not noticeably affected by compression of the thigh with a rubber tube or a blood pressure cuff during the injection of contrast material. Four exposures were made in 5 to 6 seconds, the first during the injection of the last 5 ml of the medium. The focus—film distance was in every instance 110 cm. Two to four serial roentgenograms, each consisting of 4 exposures, were obtained in every case. In many, the sound hip was examined for comparison, usually by puncture of the femoral artery on that side but occasionally by introducing a catheter to the bifurcation of the aorta from the involved side.

A total of 28 diseased hips in 25 patients were examined. These consisted of 4 cases of necrosis of the femoral head, 2 of pseudoarthrosis, 1 of carcinomatous metastases in the acetabulum, 2 of Perthes' disease (one active and one healed), 2 of suspected Perthes' disease (healed), 2 of dislocation, and 1 of Judet's plastic operation, as well as 3 of pertrochanteric and 11 of medial fracture of the femoral neck (in 3 of which it was possible to repeat the examination). The contralateral unaffected hip was also examined arteriographically for comparison in 19 cases in 4 of which the films were rejected owing to poor quality.

The main purpose was to study the posterior collum branch of the medial circumflex artery and the inferior and superior synovial arteries, in view of their size and importance. In addition, particular attention was given to anastomoses from the medial circumflex artery to the obturator and lateral circumflex arteries.

Sound hips. Fifteen cases were investigated and the following arteriographic features were invariably present:

1. Contrast-filling of the medial and lateral circumflex arteries of practically equal density, irrespective of variations in origin and course.

2. Contrast-filling of the posterior collum branch, its course being visualized to the intertrochanteric notch.

The inferior synovial artery was contrast-filled in 13 cases. The

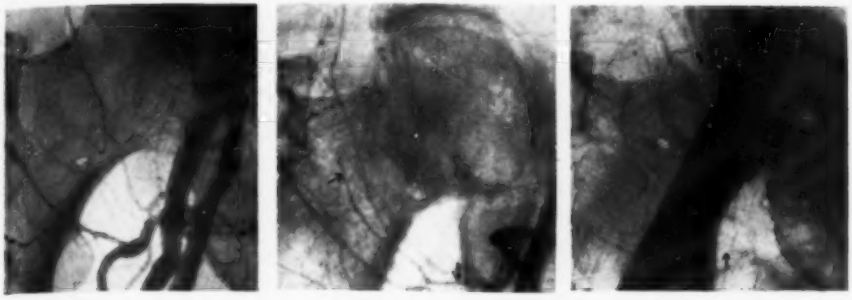

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Fig. 2. Case 1. Medial fracture of femoral neck. Dilatation of post. collum branch. a) Sound, b) affected hip, examined 5 days after fracture. Both films taken at end of injection of contrast medium. Contrast density approx. the same on both sides. Post. collum branch (↓) on fracture side appreciably wider than on opposite side. c) Affected hip after nailing examined 2 weeks after b. Film taken about 2 sec after completion of injection of contrast material. Post. collum branch (↓) still slightly filled with contrast medium; sup. synovial artery (↕) filled to lower lateral quadrant of femoral head.

vessel, which springs from either the posterior collum branch or directly from the medial circumflex artery, was as a rule visualized for a distance of 1 to 3 cm.

Less frequently, the superior synovial artery could be seen; it is the continuation of the posterior collum branch from the intertrochanteric notch.

Direct communications between the medial circumflex and the obturator arteries, as well as an acetabular branch, were demonstrable in some cases. The series is, however, too small to allow of interpretation of these variable findings.

Affected hips. Unlike ROOK, I failed to note that the general contrast-filling of vessels on the diseased side was less marked than in the sound hip; on the contrary, the anastomoses between the different arterial systems were in several cases of fracture of the femoral neck strikingly well filled. Local vascular changes were demonstrable, however, in the posterior collum branch. These consisted of: 1) dilatation, 2) decreased rate of flow and 3) arrested circulation, thus forming three distinct types.

Dilatation (Fig. 2). The diameter of the posterior collum branch was measured in the roentgenograms where it reached the inferior border of the femoral neck. For purposes of comparison only those cases were considered in which the sound hip had also been examined — *i. e.* 15 cases. In 5 of these, however, arteriography revealed arrested circulation,

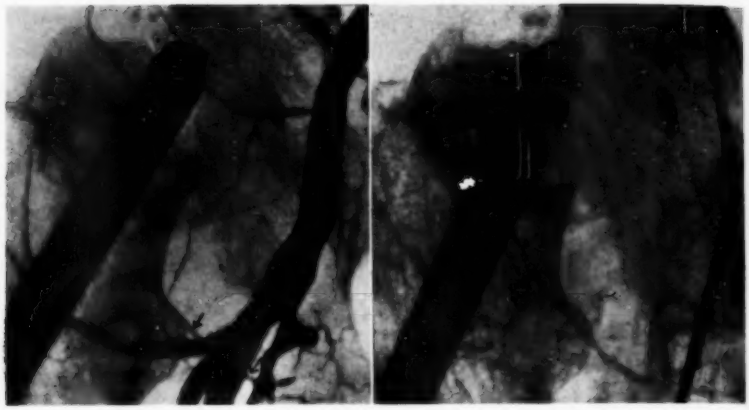

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Fig. 3. Case 2. Caput necrosis complicating medial fracture of femoral neck 27 months after accident and nailing. a) Film taken immediately and b) about 5 sec after completion of injection of contrast medium. Decreased rate of flow in posterior collum branch (↓) which is filled later (a) and drains more slowly (b) than adjacent vessels. The contrast medium in the artery and its branches in the necrotic area (↻) remains unchanged when venous phase already started (↓).

and thus no measurement was possible, leaving only 10 cases in which comparison of the affected and the unaffected side could be made. In 6 of these 10 cases dilatation of the posterior collum branch of the affected side was observed. The pathology in these 6 cases was as follows: necrosis of the femoral head — 2 (in one of these there was also pseudarthrosis of the femoral neck), pseudarthrosis following fracture of the femoral neck — 1, osteosclerotic metastases in acetabulum — 1, medial fracture of the femoral neck — 2.

Decreased rate of flow (Figs. 3, 4 and 7). This term is applied to cases in which the posterior collum branch was seen to be contrast-filled later and to drain more slowly than adjacent arteries of equal calibre. This occurred in 3 of the 4 cases of necrosis of the femoral head, in 4 of the 11 cases of femoral neck fracture, and in the 1 case of bilateral healed (suspected) Perthes' disease. Furthermore, in 4 of these 8 instances of decreased rate of blood flow, the circulation in the distal part of the posterior collum branch was arrested.

Arrested circulation (Figs. 4, 6 and 7). The flow of blood in the posterior collum branch was arrested in 5 of the 11 cases of medial fracture of the femoral neck and in both hips in which Perthes' disease was suspected. The obstruction was in every instance situated in the central portion

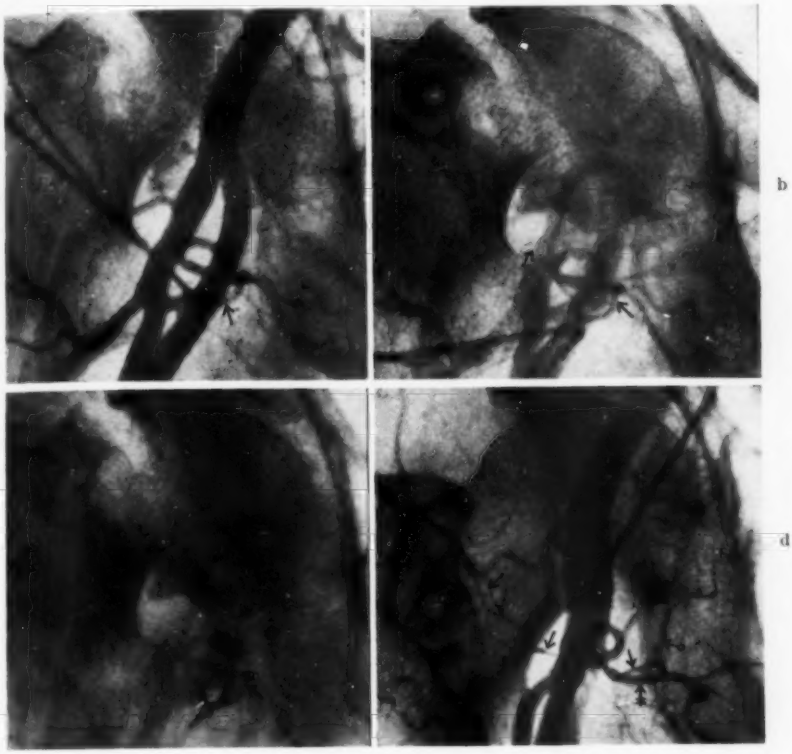

Fig. 4. Case 3. Medial fracture of femoral neck. Temporarily arrested circulation in posterior collum branch. a—c) Arteriography of the affected hip, examined 5 days after fracture. Films taken immediately (a), about 2 (b) and 4 (c) sec after completion of injection of contrast medium. Post. collum branch (↓) filled gradually to a distance of only 20 to 25 mm, the rate of flow being markedly reduced. d) Sound hip; film taken 2 sec after completion of injection of contrast medium. Normal vascular conditions. Strikingly well-developed acetabular branch (⇕) issuing from trunk of medial circumflex artery (‡).

of the vessel. Consequently, the contrast medium filled the artery for only a short distance. In 4 of the 7 cases in which the circulation was arrested, the rate of flow in the proximal portion of the artery was also markedly reduced. It was possible in three cases to repeat the examination; in one instance the obstruction to flow had disappeared (Fig. 5); in the other two cases (Case 4 in Fig. 6 c and Case 5) the circulation had not returned and the vascular conditions were largely unchanged.

Fig. 5. Case 3. Arteriography of affected hip 6 months after fig. 4 a—c. Film taken immediately after completion of injection of contrast medium. Normal circulation in posterior collum branch (↓), showing that the arrested circulation in this case was only temporary.

The following cases are characteristic of the lesions described above.

Case 1 (Fig. 2). History: Medial fracture of right femoral neck followed 6 days later by reduction and nailing. Arteriography was performed, before and after nailing, to ascertain whether the vascular state had been affected by the operation. At the initial examination, the sound hip was also examined. The contrast density was approximately equal on the two sides, despite the fact that the injection site was not exactly the same. On the other hand, the posterior collum branch on the side of fracture was appreciably wider than on opposite side. At the second examination, after nailing, the posterior collum artery was well filled with contrast medium but the superior synovial artery was also filled up to the lower lateral quadrant of femoral head. It is impossible to decide whether this was due to an improvement in circulation or to some chance circumstance.

Case 2 (Fig. 3). The case was one of a necrotic femoral head after a medial fracture of the neck and nailing. The posterior collum branch was filled later and drained more slowly than the adjacent vessels. It was particularly striking that the contrast medium in the artery and its branches in the necrotic area remained unchanged at the moment when the venous phase started.

Case 3 (Figs. 4 and 5). Arteriography first performed 5 days after a medial fracture of the neck had occurred (Fig. 4). The posterior collum branch was filled to a distance of only 20 to 25 mm, the rate of flow being markedly reduced. The arteriogram of the contralateral side showed normal vascular conditions; a strikingly well-developed acetabular branch, issuing from the medial circumflex artery was also seen. The second arteriographic examination of the involved side 6 months later (Fig. 5), after reduction and nailing, showed the circulation to be neither arrested nor decreased. The obstruction, then, was only temporary.

Case 4 (Fig. 6). Arteriography was performed the day after the medial fracture of the femoral neck occurred. On the sound side the posterior collum branch was seen to be well developed, whereas on the affected side the branch was narrow and relatively poorly filled. It did not traverse the inferior border of the femoral neck but continued in the inferior synovial artery. Arteriography, repeated 2 months later after reduction and nailing, showed the conditions to be largely unchanged. The posterior collum branch was filled only up to the inferior border of the femoral neck, at which point small anastomoses had developed.

Case 5 (Fig. 7). A man, aged 49, had had hip trouble since his sixth year. Roentgenographic examination suggested that the condition might be bilateral coxa plana (Perthes' disease). The greater part of the right femoral head was reabsorbed, only a small portion

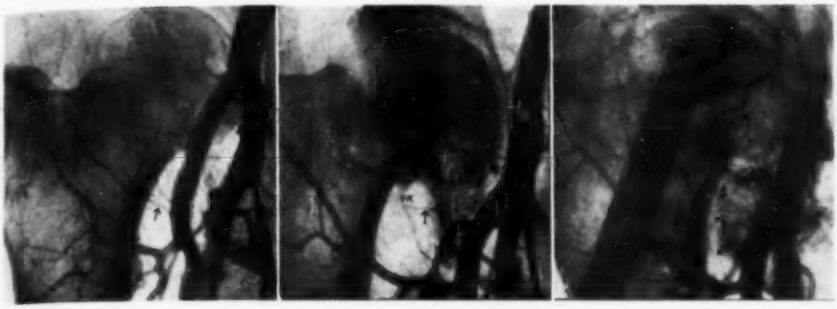

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Fig. 6. Case 4. Medial fracture of the femoral neck. Permanently arrested circulation in posterior collum branch. a) Sound and b) affected hip examined the day after fracture. Films taken immediately after completion of injection of contrast medium. Post. collum branch (↓) on normal side well developed but on fracture side narrow and shortened; it does not traverse inferior border of femoral neck but seems to continue in inf. synovial artery (↕). c) Arteriography 2 months later, after reduction and nailing. Film taken 3 sec after completion of injection of contrast medium. Vascular conditions largely unchanged. Small anastomoses from the rest of post. collum branch (↕).

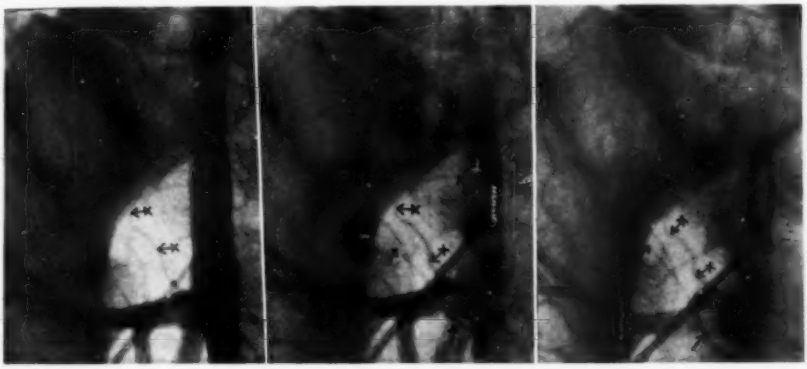

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Fig. 7. Case 5. Deformity probably after coxa plana (Perthes' disease). Films taken 4 (a), 5 (b), and 6 (c) sec after completion of injection of contrast medium. Post. collum branch (↓) filled later than adjacent arteries and shortened as it does not traverse inferior border of femoral neck. Inf. synovial artery (↕) strikingly well-developed and filled with contrast medium.

of its lower medial quadrant remaining intact. The proximal portion was sclerotic. On the left side, the femoral head was smaller than normal and grossly deformed; the neck was shortened and there was considerable coxa vara deformity. On arteriography, the vessels on both sides were well filled with contrast medium. On the right side, however, the posterior collum branch was seen to be filled for only a short distance.

Furthermore, the flow of blood in that portion of the artery was decreased. On the other hand, the inferior synovial artery was relatively large and well filled with contrast material, its course running proximally to the remaining portion of the femoral head. On the left side, no posterior collum branch was visible; the vascular anatomy was otherwise similar to that of the right side. Arteriography on both sides repeated 11 months later showed the vascular conditions unchanged.

The appearances suggested obliteration of the whole of the left and the distal part of the right posterior collum branch, since the area they supply (the femoral head) had been largely reabsorbed. On the roentgenologic evidence it was impossible to state whether the bone lesion or the vascular lesion was the primary factor.

The arteriographic appearances of the posterior collum branch of the affected hips may be taken to be pathologic since they were not noted in the sound hips. Dilatation of the posterior collum branch is suggestive of hyperaemia following upon tissue damage or vascular injury not capable of demonstration. A decreased rate of flow in the artery may be due to stasis in arterial or precapillary vessels. Arrested circulation, even if only temporary, may result from obliteration of vessels due to rupture, torsion, thrombosis, or some other cause.

The relation between the changes demonstrated arteriographically, the healing of the fracture, and the development of necrosis of the femoral head, will be studied further in a larger series of cases.

Acknowledgment

The author expresses his thanks to Prof. K. LINDBLOM for permitting him to carry out the anatomic investigations at the Roentgendiagnostic Department of Karolinska Sjukhuset, Stockholm.

SUMMARY

Vessels of most importance in the nutrition of the femoral head were studied by arteriography *in vivo*. The total of 28 affected hips examined included 3 cases of pertrochanteric fracture and 11 cases of medial fracture of the femoral neck. The sound hip was examined in 15 of the cases. Lesions of the posterior collum branch of the medial circumflex artery disclosed were of three types and consisted of 1) dilatation, 2) decreased rate of flow, 3) arrested circulation. The changes were not present in the sound hips, and are therefore taken to be pathologic.

ZUSAMMENFASSUNG

Gefässe von wesentlicher Bedeutung für die Ernährung des Femurkopfes wurden mit Hilfe der Arteriographie *in vivo* studiert. Die 28 untersuchten kranken Hüften enthalten 3 Fälle mit pertrochanteren Frakturen und 11 Fälle mit medialen Frakturen des Femurhalses. In 15 Fällen wurde auch die gesunde Hüfte untersucht. Verletzungen des hinteren Collumzweiges der A. circumflexa medialis waren dreierlei Art: 1) Dilatation, 2) Abnahme der Strömungsgeschwindigkeit, 3) Aufhören der Zirkulation. Derartige Veränderungen fand man in den gesunden Hüften nicht: sie werden daher als pathologisch betrachtet.

RÉSUMÉ

L'auteur a étudié par artériographie *in vivo* des vaisseaux d'une extrème importance pour la nutrition de la tête fémorale. Le total des 28 hanches malades examinées comprenait 3 cas de fracture cervico-trochantérienne et 11 cas de fracture sous-capitale du col du fémur. La hanche saine a été examinée dans 15 de ces cas. Les lésions de la branche cervicale postérieure de l'artère circonflexe interne que l'on a trouvées étaient de trois types: 1) dilatation, 2) diminution du débit, 3) arrêt de la circulation. Ces modifications n'existaient pas sur les hanches saines et sont donc considérées comme pathologiques.

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THE TREATMENT OF MALIGNANT MELANOMA WITH SPECIAL REFERENCE TO THE POSSIBLE EFFECT OF RADIOTHERAPY

by

Lorentz Nitter

Malignant melanomas are among the most virulent and dreaded of all tumors. In spite of the fact that primarily these tumors should be the most accessible of all kinds of cancer to radical primary excision, they take their place among the groups of tumors which yield the lowest percentage of cures. They form an important group, not only for this reason, but also because few other tumors are interpreted so differently by clinicians and opinions are so divided as to the best kind of therapy.

The most widely held opinion is that malignant melanomas are radioresistant and that treatment should be mainly surgical (1, 4, 10, 14, 16, 17, 18, 19, 20, 21, 22, 25). In their efforts to prevent the growth and spread of these tumors, the surgeons who hold this opinion have treated them more and more radically. Broad excision of the primary tumor and the underlying fasciae is recommended together with regional prophylactic dissection of the glands in one or more regions. PACK and his collaborators, in particular, have employed this method and, in suitable cases with clinically demonstrable lymph node metastases, have, often with extensive surgery, removed the primary tumor with the underlying fasciae and the regional lymph glands in continuity.

PACK's material, which is the most extensive, includes a total of 1,190 cases in the period 1917—1950. In an article in 1952 (21) PACK and his collaborators discuss the final results in detail. Of 744 patients treated

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during the period 1917—1945, 575 have been the object of subsequent evaluation. 123 patients, or 21.4 per cent, are alive and without recurrences after 5 years or more. These comprise 16.5 per cent of the entire material of 744 patients. He points out the steady improvement in the results from 10 per cent in the period 1917—1925 to 27.6 per cent in the period 1936—1940. From 1941 to 1945 there is a slight decrease to 26 per cent which is ascribed to the lack of civilian physicians during the war. PACK concludes that the cause of the improved results is the increasingly more radical surgery applied in recent years.

On the other hand, a number of radiotherapists claim that these tumors are more or less radiosensitive and that in many cases may be treated advantageously with roentgen rays or radium (3, 8, 9, 11, 13, 15).

As pointed out by ELLIS in particular, radiotherapy has not been given a fair chance to show what it can do with this form of tumor because most authors consider it radioresistant. The large majority of patients, therefore, have been treated primarily with surgery. In many cases the patients have received radiotherapy only after recurrences and metastases. ADAIR, who is in favour of surgical treatment, claims that he has seen favourable results of radiotherapy in only 2.5 per cent of cases. On the other hand, the proponents of radiotherapy claim that their results are quite as good as those obtained by surgery. A more frequent practice in recent years has been the administration of 'hypermassive' doses on the primary tumor, up to more than 30,000 r in fractionated doses, with apparently good results. This type of therapy is discussed in detail by CHAOUL among others, but the period of observation is short.

In the published reports on radiotherapy exclusively, it is often difficult to find any exact figures which might indicate that this method yields equally good results. As it is also considered contra-indicated to take a biopsy, the microscopic confirmation of the diagnosis is lacking in many cases. It must thus be assumed that a number of these tumors were benign nævi. However, it should be emphasized that in the literature in defense of this type of therapy there are a number of cases in which the primary tumor has proved to be surprisingly radiosensitive.

Finally, there is a third group which claims that the best results are obtained by means of a combination of the two types of therapy. They believe that the same, or even better results, may be obtained with less radical surgery when the treatment is supplemented with post-operative, and in some cases pre-operative, radiotherapy, sometimes both. In Scandinavia BERVEN has employed this treatment. The reader is referred to two publications from Radiumhemmet, Stockholm, on a total material of 422 patients in the period 1921—1948 (23, 24).

In Radiumhemmet's series of 341 cases (SYLVÉN), the over-all five-year survival was 26.7 per cent and the over-all end-result in 1948, including all patients, was 23.7 per cent. For Stage I, which includes patients without lymph node metastases, the five-year survival figure is 48.3 per cent, while in Stage II with lymph node metastases in one region it is 8 per cent. SYLVÉN claims that Radiumhemmet's relatively good result for the entire material is due to the fact that the patients came to treatment at an early stage, as 55 per cent of them are classified in Stage I. SYLVÉN concludes that in suitable cases more radical surgery might be necessary to improve the results further, as they seem to be better when lymph node metastases are treated surgically. PACK reports about 14 per cent five-year survivals for this group.

When evaluating the various materials and therapeutic results, it must be remembered that the starting point, especially as regards this form of tumor, may vary considerably in respect to the extent of growth and metastases before therapy is initiated. It is universally agreed that treatment must be administered as early as possible and that it is the first treatment of the primary tumor which is decisive for further developments. Most authors complain, however, that the difficulty in making a choice of therapy presents itself immediately, as most patients have had the primary tumor removed either shortly or some time before admission to a surgical or radiotherapeutic department. It is often not known how radically the primary tumor has been removed, and must be gauged from information supplied by the patient as to the size of the primary tumor, and from the scar of the primary excision which the patient exhibits on admission. In many cases the patient is admitted for radical surgery or radiotherapy only after local recurrence in the primary excision, sometimes also with lymph gland metastases. SYLVÉN has tried to make a classification into stages in order to give a clearer picture. This is usually lacking in other publications and comparison of the materials is therefore very difficult. It should be emphasized, however, that stage classification of this tumor form is particularly uncertain.

Furthermore, the peculiar biology and growth of this group of tumors must be considered. In many cases it is very difficult from the microscopic picture to differentiate between a benign nævus and a tumor which has become malignant; sometimes it is quite impossible and places special demands on the pathologist (2, 5, 6, 7).

The typical melanomas may readily be diagnosed clinically. On the other hand, there are many which exhibit such an atypic clinical picture that even the most experienced clinician may be mistaken and surprised.

It will thus primarily be the result of the histologic examination,

supplemented with clinical observations as to the growth of the tumor, 'irritation', and changes in pigmentation, together with the age of the patient and possible alterations in the hormonal milieu, which will be decisive for the diagnosis and therapeutic procedure.

PACK, who has by far the most extensive material on this tumor group, has demonstrated several factors of importance in the therapeutic approach.

1. The value of immediate treatment, as only one month's delay after the microscopic diagnosis has been made reduces the percentage of cures from about 40 to 17.

2. In a material where gland dissection was performed with negative microscopic findings the five-year survival figure was 40.5 per cent while with positive findings it was 14.1 per cent. This clearly demonstrates the significance of hematogenous dissemination for these tumors, as the figure for the first group is disappointingly low.

3. Furthermore, by careful examination of clinically undemonstrable lymph gland metastases, he found that subsequent lymph gland dissection revealed tumor cells in 50 per cent. Although these observations are made on a limited material, they demonstrate the necessity of prophylactic treatment of the lymph gland region. In recent years, since we have employed prophylactic gland dissection rather extensively at The Norwegian Radium Hospital, we have also confirmed this observation in a number of cases.

Own material

A total of 393 patients have been admitted to The Norwegian Radium Hospital under the diagnosis 'malignant melanoma' in the period 1932 to 1 January 1954. Of these, 192 were admitted before 1 January 1949. The prepubertal melanoma, three cases prior to 1949, alive and without recurrences, are not included in this compilation. Melanomas of the eye, which have a much more favourable prognosis than other localizations, are also excluded from this material. All of the patients have been controlled, some of them for many years, and their fate on 1 January 1954 is known.

In all cases the diagnosis has been verified microscopically. There are many microscopic sections from each patient in various stages of the development of the disease, and the entire histologic material has been carefully examined by J. EFSKIND of the Pathology Department of this hospital. This material is being studied and will be the subject of a subsequent publication.

Figures from the Norwegian Cancer Registry show that on the average there are 70 to 80 new cases of malignant melanoma in Norway per year in a population of a little over three million, or about ten per cent of the primary malignant tumors of the skin.

The material shows a marked increase in the number of patients admitted under this diagnosis in recent years. There are 170 patients alive with or without recurrences on 1 January 1954. Of the 223 patients who succumbed, 24 died of intercurrent diseases. The material includes a total of 220 women of whom 111 (approx. 50 per cent) are alive, and 173 men of whom 59 (approx. 33 per cent) are alive.

It is the group of patients from before 1949 with an observation time of more than five years which forms the basis for the present evaluation. Table 1 presents a more detailed summary of these 192 patients. Before 1939 only a few patients were admitted each year, and from 1940 to 1944 an average of ten patients annually. In 1948 the figure had reached 40 per year and this figure remained fairly constant during the next five-year period. However, in 1954 we admitted 67 new cases.

Table 1

Summary of 192 patients before 1 Jan. 1949 with more than five years observation time. (IC): Dead of intercurrent diesase.

Period	Number	Five-year survival			Ten-year survival		Total dead 1 Jan. 1954	(IC)
		Without recurrence		With recurrence	Without recurrence	With recurrence		
1932—1939.....	38	10	26.3 %	2	9	1	29	(6)
1940—1944.....	50	14	28 %	3	11		40	(1)
1945—1948.....	104	31	29.8 %	3			75	(10)
1932—1948.....	192	55	28.6 %	8			144	(17)

There is a strikingly constant proportion of five-year cures from 1932 up to 1948. It appears that 28.6 per cent of the total material was without recurrence after five years and 47, or 24.4 per cent, were alive and without recurrence on 1 January 1954 after 5 to 22 years observation.

Among the deaths in this material, 17 are ascribed to intercurrent diseases (IC). If the figures in Table 1 are corrected according to MacDonald, those who died of intercurrent diseases, as well as 13 who received no treatment, are excluded. This correction gives a five-year survival of about 34 per cent in the 'determinate' group, and an end-result of 29 per cent as at 1 January 1954.

Table 2 shows the age and sex distribution of the 192 patients admitted before 1949.

The number of women in the age group 40 to 49 years is remarkably high with 25 patients of whom only 4 are alive after five years. This may have some connection with the hormonal alterations associated with the onset of the menopause. Otherwise the prognosis is better for women than for men, as is also evident from other compilations.

In 167 patients the primary tumor was situated in the skin (Table 3). A remarkably large number were present in the head and neck, 50 of

Table 2

Age and sex distribution 1932—1948. Patients alive on 1 Jan. 1954.

Age	Women		Men	
	Total	Alive	Total	Alive
10—19			2	1
20—29	8	3	14	6
30—39	14	8	13	4
40—49	25	4	10	2
50—59	17	7	18	2
60—69	13	2	15	1
70—79	20	6	15	2
80—89	5	0	3	0
	102	30	90	18

these being on the face. Localization on the foot is prominent with 31 cases, only 6 of which are alive after five years. The explanation of the rather poor prognosis for this situation is possibly the special circulatory mechanism in the lower extremities as well as chronic irritation caused by shoes. This will probably afford the basis for a marked tendency to dissemination when a preexisting nævus becomes malignant. Of the 45 still alive, 1 has a local recurrence.

Table 3

Prognosis of melanoma of skin according to site 1932—1948. (IC): Dead of intercurrent disease.

Skin localization	Number	Alive 1 Jan. 1954	Dead	(IC)
Head and neck	66	16	50	(10)
Trunk	36	10	26	
Arm	8	3	5	
Leg	23	8	15	(2)
Foot	31	6	25	(4)
Big toe	3	2	1	
Total	167	45	122	(16)

Table 4 presents a summary of the situation of the primary tumor in the remaining 25 patients. In 11 of them the primary tumor was localized to the vulva and the vagina. The site of the primary tumor was unknown in six patients. On the whole this group has a poor prognosis which must be ascribed partly to the situation, these tumors being detected late. The opportunity for radical treatment is naturally also much more limited in these cases.

Table 4

Prognosis according to 'other localizations' 1932—1948. (IC): Dead of intercurrent disease.

Other localizations	Number	Alive 1 Jan. 1954	Dead	(IC)
Palate	2		2	
Lip	1	1		
Vestibulum nasi	1		1	(1)
Gingiva	1		1	
Mamma	1		1	
Vagina	3		3	
Vulva	8	1	7	
Anus	2		2	
Unknown	6	1	5	
Total	25	3	22	(1)

Therapeutic principles and results

Treatment from 1932 to 1948 has, on the whole, consisted of combined surgical and radiation therapy as will be seen in the following. Surgical intervention has been extremely conservative in some cases but has practically always been followed by postoperative radiotherapy — a radium mould on the scar area after primary excision to include the adjacent 2 or 3 cm of the surrounding skin. Teleradium has also been used in certain cases, in both instances with a total skin dose of about 3,500 r. Postoperative roentgen treatment was usually applied to gland regions, and in some cases prophylactically to regional glands when these have not been dissected. The dose varied from 3,500 to 4,000 r, 175 kV, 4 mA, filter 1 mm Cu, focal—skin distance 50 cm. In a few cases teleradium was used on the gland areas with the same total dose.

In the five-year period since 1949 we have employed much more radical surgical intervention but have tried to continue the principle of postoperative radiotherapy. As the control period for this last group is obviously much too short, it will be particularly the possible effect of our additional radiotherapy which I shall attempt to evaluate, in other words the group of patients treated before 1 January 1949 with an observation time of a least five years.

Of 167 patients with the primary tumor situated in the skin, 45 survived more than five years, 1 of these with a recurrence. Thus 26 per cent are without recurrences. If the table is corrected according to MACDONALD, excluding intercurrent deaths and untreated cases, the result is about 30 per cent, the same as SYLVÉN's.

The prognosis for 'other localizations' is, as already mentioned, poor, as only 3 out of 25, or 12 per cent, are alive and without recurrence after more than five years.

In order to study the therapeutic results on the various development stages of the disease, all the patients have been classified according to the stage of the disease on first admission to the hospital. Such a classification into stages, necessarily based on clinical supplemented by roentgen examination, is naturally not without errors. The classification is the same as that used by SYLVÉN and is defined as follows:

Stage I. Localized melanoma confined to the skin. Local recurrences and nearby deposits in cutaneous lymphatics are included.

Stage II. Cases with regional lymph node metastases confined to one gland station only.

Stage III. Metastatic involvement of two or more groups of glands, and cases with distant metastases evidencing generalized tumor process.

Table 5 gives a summary of the stage classification and the therapeutic results for those patients in whom the *primary tumor was localized to the skin*. Of 107 patients in Stage I, 35 are alive after more than five years, 1 with a recurrence. Thirteen of these patients have been observed for more than ten years, 5 of them more than 15 years.

Table 5

Stage classification and therapeutic results for group of patients with primary tumor localized to skin. (IC): Dead of intercurrent disease.

Skin	Number	Alive 1 Jan. 1954	Dead	(IC)	Survivors %
Stage I	107	35 Over 15 yrs: 5 10—14 » 8 5—9 » 22	72	(13)	32
Stage II	42	10 Over 15 yrs: 1 10—14 » 2 5—9 » 7	32	(3)	24
Stage III	18	0	18		
	167	45	122		

In Stage II, which includes 42 patients, 10 are alive after more than five years (3 of them more than ten years).

In Stage III no patients have survived for five years. The results for Stage I are somewhat poorer than in SYLVÉN's material. On the other hand, the result in Stage II is surprisingly good; this will be discussed below.

The same classification has also been applied to the group with *other localizations* (Table 6). It is striking that 2 of the 8 patients in Stage II are alive 14 and 5 years, respectively, after the first treatment. In both cases there were positive microscopic findings in excised glands; the glands were not removed in continuity. In 1 case the primary tumor was situated in the vulva with lymph gland metastases to the groin; teleradium therapy (4,000 r) was applied to the groin. In the other patient, also with positive microscopy from an excised gland and also in the groin, the primary tumor was possibly situated subungually on the foot but this was not verified with certainty. Ordinary roentgen treatment was given to the groin and she has survived for five-and-a-half years.

Table 6

Stage classification and therapeutic results for group of patients with other localizations of primary tumor. (IC): Dead of intercurrent disease.

Other localizations	Number	Alive 1 Jan. 1954	Dead	(IC)
Stage I.....	8	1 (10 yrs)	7	(1)
Stage II	8	2 (14 yrs) (5 yrs)	6	
Stage III.....	9	0	9	
	25	3	22	(1)

It is generally claimed that the primary treatment is the most important and should be given at as early a stage as possible. The difficulty in evaluating this kind of material, however, is just the fact that primary treatment has usually been administered before admission to hospital. In the entire material of 192 patients, primary excision in Stage I or gland dissection in the two subsequent stages had been performed on 125 patients, or 65 per cent of the entire material, before admission to the hospital. Among these, 41 were admitted with recurrence after previous treatment at other hospitals.

Unfortunately, 43 of the patients had received obviously incorrect

treatment before admission. The primary tumor had often been removed by tying off with thread and by electrocauterization, and attempts made to remove it with caustic ointments or liquids. It appears that in a number of cases no microscopic examination was made on the excised tumors since they did not seem macroscopically to be malignant.

The importance of the primary excision or the primary treatment in general is obvious where Stage I is concerned. Among our 107 patients with tumors situated in the skin, 62 had had the primary excision performed outside the hospital, and only 34 of them after admission. The remaining 11 patients received only primary radiotherapy. It is often difficult to determine just how radically the primary excision was performed before admission; in many cases the size of the scar indicated a very conservative procedure.

As appears from Table 7, the primary excision with subsequent radium mould was performed in 75 per cent of the cases and is the most commonly employed treatment at our hospital in Stage I. Of these patients 29 are alive (one with recurrence) at the end of the control period. Of the 49 in this group who succumbed, 8 died of intercurrent diseases. When correction is made according to MacDonald, 40 per cent of the patients who received this treatment are alive and without recurrence after more than five years, which is about the same result as that reported by Pack with much more radical methods. However, it should be mentioned that 3 patients probably owe their lives to subsequent gland dissection. In the entire group of 107 patients, gland dissection was performed subsequently on 19, 3 of whom are alive.

Table 7

Primary treatment in Stage I for tumors localized to skin. (IC): Dead of intercurrent disease.

Skin	Primary treatment Stage I	Number	Alive 1 Jan. 1954	Dead	(IC)
Electrocautery		3	0	3	(1)
Excision	+ radium mould	78	29	49	(8)
»	+ teleradium	10	2	8	(4)
»	+ roentgen	4	2	2	
»	+ intubation	1	1		
Radium mould		6	1	5	
Teleradium		4	0	4	
Intubation		1		1	
		107	35	72	(13)

In the entire group, 15 patients received radiotherapy for gland metastases. One of these is alive; this patient was treated primarily

with excision + intubation of radium needles; subsequently there were positive microscopic findings in the gland region before radiotherapy was administered. Thus a total of 34 of 107 patients received subsequent treatment to gland regions. Four of these are alive, gland dissection having been performed in 3 and the gland region irradiated in the other. It is reasonable to assume that some of the remaining 30 patients could have been saved by earlier gland dissection.

However, our results are no poorer than in materials where extremely radical primary excision was performed. With due consideration of the cases in the present material in which the primary excision was conservative, it is justified to assume that the postoperative radiotherapy has been significant, and especially our radium mould therapy which covers a skin area of several cm around the scar. This therapy affords homogeneous penetrating irradiation of the skin, at least as deep as the fasciae.

Among the 107 patients in Stage I, 28 had received prophylactic gland irradiation. Table 8 presents a summary of the possible effect of this treatment in 24 of 78 patients in Stage I who received the same primary treatment, excision + postoperative radium mould. The percentage is corrected according to MACDONALD. The figures are not large and the difference between the two series with regard to per cent survivors not very marked, but the result seems to suggest a somewhat better prognosis for the patients who received prophylactic gland irradiation.

Table 8

Summary of possible effect of prophylactic gland irradiation in Stage I with primary tumor localized to skin. (IC): Dead of intercurrent disease.

Skin	Number	Alive 1 Jan. 1954	Dead	(IC)	Survivors (%; corrected)
Prophylactic gland irradiation	24	11	13	(2)	50
No prophylactic gland irradiation	54	18	36	(6)	37.5
	78	29	49	(8)	

Table 9 gives a more detailed summary of the therapeutic results for Stage II when the *primary tumor is situated in the skin*. This classification into a positive, microscopically verified group and a clinical group suggests effect of radiotherapy on gland metastases. Of the 7 patients who are alive in the microscopically verified group, the gland region was irradiated in 5 after biopsy had revealed positive findings

from the gland region. Two of these have received no further treatment. Gland dissection was performed in 2 of them, two and four months later, respectively. Microscopic examination of the removed glands was negative in both; in 1 case only a residual gland was removed and microscopy showed considerable effect of the radiation on the tumor cells.

Table 9

Therapeutic method applied to gland region in Stage II when primary tumor was localized to skin. (IC): Dead of intercurrent disease.

Skin Stage II	Alive 1 Jan. 1954	Dead	(IC)
With positive biopsy from lymph node	7	11 (1)	
	Radiotherapy 5	Radiotherapy 4	
	Gland dissection + radiotherapy ... 2	Gland dissection + radiotherapy 6	(1)
		Gland dissection ... 1	
Clinical Stage II	3	21 (2)	
	Radiotherapy (roentgen 2, teleradium 1) 3	Radiotherapy ... 17	(2)
		Gland dissection + radiotherapy ... 2	
		Gland dissection .. 2	
42	10	32	(3)

Ordinary gland dissection followed by radiotherapy was performed on the two others in the group of survivors.

In the group classified as clinically probable Stage II, the 3 survivors received radiotherapy only in the gland region, 2 with roentgen therapy and 1 with teleradium.

Conclusions

The possible effect of radiotherapy in the entire material is best obtained by considering the treatment administered to the survivors.

Of the 35 survivors in Stage I, all received some kind of radiotherapy primarily, as a rule subsequent to previous and often extremely conservative excision of the primary tumor. Gland dissection was later performed in 3 of these cases and probably saved their lives. In 1 additional case the gland region was irradiated only after a positive biopsy from an extirpated gland.

In the entire material of Stage II there are 12 patients who are alive without recurrences, and in 9 of these the stage has been verified microscopically from extirpated glands. Ten of these 12 patients received radiotherapy for gland metastases as the principle treatment.

Fig. 1. Woman, aged 65. Primary tumor on left cheek with gland metastases in neck. Biopsy: Malignant nævus cell tumor. Therapy: Radium mould left cheek for 4 days, 3,720 r.

Fig. 2. Same case two months later. Good primary effect of radiotherapy. Tumor almost completely disappeared. Residual tumor extirpated. Microscopy of excised tissue revealed no definite tumor cells.

Our results in Stage I with postoperative radium mould therapy seem to be no poorer than in other materials where the principal primary treatment has been pure radical surgery. Furthermore, prophylactic gland irradiation in Stage I seems to have had some effect as the end-result for this group is somewhat better than for the patients who received no prophylactic gland irradiation.

The figures are small but they indicate that radiotherapy cannot be disregarded for this type of tumor. The material also affords some direct evidence that radiotherapy in ordinary doses may have a very good primary effect (Figs. 1 and 2). The frequently extensive surgical intervention recommended for this type of tumor may be a great strain on the patient. In our opinion surgery should be no more extensive than to allow postoperative radiotherapy immediately after the primary intervention. Prophylactic gland treatment should always be administered in Stage I. In choosing between prophylactic gland dissection or gland irradiation it is necessary to individualize. The patient's age and general condition must be considered as well as the localization of the tumor in relation to the regional lymph glands before resorting to extensive surgery.

As regards this tumor form, it is probable that in many cases the inherent growth energy and mode of dissemination are more decisive for the result than the therapeutic methods employed. However, there can be no doubt that the correct treatment of the primary tumor may be decisive for the further fate of the patient. Further, it is important to remove all nævi which are so situated as subsequently, through irritation, liable to become malignant. At the out-patient department of the Norwegian Radium Hospital we have in recent years had about 300 patients annually with moles which have either shown clinical signs of alteration or are exposed to irritation because of their situation. Further examination has revealed a malignant nævus in about 10 per cent of these cases; in a number of them the microscopic findings have been surprising. It must be assumed that these patients have been caught at a very early stage of the disease, and that there is hope that a later compilation of our material will show that just these patients have a better prognosis.

SUMMARY

A review is given of a material of 393 cases of malignant melanoma, 192 of which with more than five years observation time; the latter group is discussed in detail. Treatment has consisted chiefly of surgery combined with radiotherapy, often with postoperative radium moulds on the scar region after primary excision. In some cases in Stage I, prophylactic gland irradiation seems to give a better prognosis while there appears to be a definite effect of radiotherapy on gland regions from which positive biopsies have been obtained. The author concludes that postoperative radiotherapy cannot be disregarded for this tumor form. The results in this material seem to be equally good as those in which purely radical surgery has been practised.

ZUSAMMENFASSUNG

Der Verfasser gibt eine Übersicht über ein Material von 393 Fällen mit malignen Melanomen, von denen 192 länger als 5 Jahre beobachtet worden sind. Die letztere Gruppe wird eingehend diskutiert. Die Behandlung war hauptsächlich kombiniert chirurgisch-radiotherapeutisch; oft wurde nach dem primären Eingriff Radium auf die Operationsnarbe appliziert. In einigen Fällen im Stadium I scheint die prophylaktische Bestrahlung der regionären Lymphdrüsen die Prognose zu verbessern. Ein definitiver Effekt der Bestrahlung auf Drüsengegenden, von denen man positive Biopsien erhalten hat, scheint vorzuliegen. Der Verfasser schliesst hieraus, dass postoperative Strahlentherapie bei dieser Tumorform nicht ignoriert werden kann. Die Ergebnisse sind allem Anschein nach in diesem Material ebenso gut wie in anderen Zusammenstellungen, in welchen ausschliesslich radikale Chirurgie praktiziert worden ist.

RÉSUMÉ

L'auteur analyse une série de 393 cas de mélanome malin, dont 192 ont été suivis pendant plus de cinq ans; il étudie ce dernier groupe de façon détaillée. Le traitement

a consisté principalement en chirurgie associée à la radiothérapie, souvent radiumthérapie post-opératoire avec appareil moulé sur la région de la cicatrice après excision préalable. Dans certains cas au Stade I l'irradiation prophylactique des ganglions lymphatiques paraît donner un pronostic plus favorable; d'autre part, il semble que la radiothérapie sur les régions ganglionnaires où des biopsies ont été positives ait un effet certain. L'auteur en conclut qu'il ne faut pas négliger la radiothérapie post-opératoire dans cette forme de tumeur. Les résultats sur cette série semblent être aussi bons que ceux des cas où on a fait uniquement une chirurgie radicale.

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RADIATION DOSIMETRY USING ALKALI HALIDE CRYSTALS AND THE ABSORPTION OF BETATRON BREMSSTRAHLUNG IN WATER AND BONE

by

D. Kahn

Dosimeters for electromagnetic radiation are designed either to record the instantaneous dose rate or to integrate the dose rate over the time of exposure. The simultaneous indicating instrument is prone to suffer from the effect of the intense radiation field on parts of the dosimeter other than the detecting element such as insulators, signal leads, etc. The integrating type of dosimeter either requires extensive manipulation as is the case with the chemical type or suffers from a somewhat limited range as is the case with a thimble chamber.

The alkali halide photoconductive dosimeter seemed to combine ease of measurement with a wide range, and such a dosimeter was constructed and some of its characteristics as a general integrating radiation dosimeter were determined. In addition, this dosimeter was employed to measure the linear absorption coefficient of betatron γ-radiation in water and bone absorbers.

Alkali halide crystals, when irradiated with roentgen and gamma rays, exhibit a wide variety of phenomena which may be used to indicate and measure such radiations (FRIEDMAN and GLOVER). For routine dosimetry in the laboratory, the utilization of photoconductivity in the crystal subsequent to radiation combines the advantages of suitable sensitivity and ease of measurement. The resulting photoconductivity depends on structure imperfections induced in the crystal, a perfect crystal lattice showing no photoconductivity. Under irradiation an electron can be ejected from the halide valence band and trapped at a nega-

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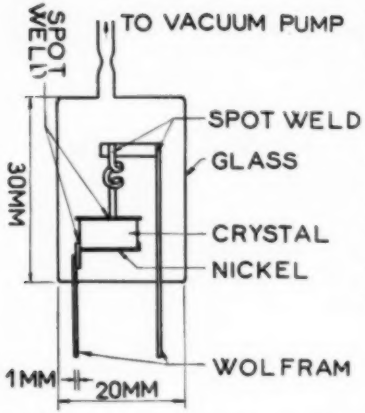

Fig. 1. Construction of the single crystal dosimeter.

tive ion vacancy, forming an F-center (MOTT and GURNEY). If the crystal is exposed to visible light while in an electric field, the trapped electrons are liberated and produce a net drift before being permanently trapped at neutral halogen atoms or returned to the valence band in some other way. A measurement of this current, and hence the F-center density, gives a measure of the radiation dosage received by the crystal.

Dosimeter construction

The dosimeters investigated here were constructed of KBr (supplied by Taylor, Taylor and Hobson Ltd., Leicester, England). The detecting element was first constructed using a fragmented single crystal supported between two concentric wire-gauze cylinders (LICHTENSTEIN). Although this type of dosimeter is easily made in a small size, it suffers from the disadvantage that the output pulse is non-linear for dosages above approximately fifty roentgens, due to the collapse of the field in the crystal fragments caused by polarization effects (LICHTENSTEIN). Consequently, a dosimeter with a single $1 \times 1 \times 0.5$ cm crystal of KBr was constructed. The crystal was mounted between thin nickel plates and enclosed in a glass capsule, as shown in Fig. 1. The dosimeter was then heated to approximately 350° C, evacuated with a diffusion pump to drive off any water adhering to the crystal faces, and the glass capsule sealed. A six volt, ten watt lamp and the crystal holder were placed in a 0.1 mm thick copper shield to constitute the dosimeter.

To carry out radiation dosage measurement, the following procedure was used: within one minute after the irradiation, a potential difference of 280 volts was applied to the nickel plates across the crystal through a 10^{10} ohm resistor and 200 $\mu\mu$f condenser in parallel. The crystal was then illuminated for approximately ten seconds by means of the lamp in the dosimeter, which was energized by a storage battery. The charge which accumulated on the condenser as a consequence of the photoconductivity of the crystal was measured by means of a vibrating reed electrometer. The time required for the charge to accumulate on the input condenser was short compared to the two second time constant of the resistor capacitor network. It follows, therefore, that the ten second illumination was much more than was necessary to produce the complete

current pulse corresponding to excitation of all the F-centers, and reasonable variations in the light intensity would not change the electrometer reading. An auxiliary experiment in which a five watt bulb was substituted for the one ordinarily used, without changing the pulse amplitude, confirmed this conclusion.

To obtain a preliminary calibration of the dosimeter it was exposed at a distance of one meter to irradiation from a wolfram target, glass walled X-ray tube operated at 175 keV and 20 mA with a 0.5 mm Cu. and 1.0 mm Al filter. Diagram 1 shows the readings obtained for various exposures plotted against the dosage measured with a Victoreen type thimble chamber placed next to the KBr dosimeter. Apparently the results obtained are not affected by any thermal bleaching of the F-centers during irradiation or during the period between irradiation and measurement. This follows from the linear nature of the response curve, since the dose, which varied by more than a factor of ten, was always given at the same rate. The pulse at zero dose is presumably due to a surface leakage caused by some residual moisture. It was observed that the residual current did increase somewhat after the first few irradiations, an effect which may be attributed to trapped electrons not entirely removed by the illumination (ALGER).

An improved electronic circuit for measuring the pulse height is being constructed (HART). This instrument will eliminate the need for the added input capacitance and resistance and should minimize the effect of any steady currents compared to the photoconductive pulse.

Experimental results

In order to investigate the energy dependence of the crystal dosimeter relative to that of a Victoreen type thimble chamber, irradiations were made in which both dosimeters were exposed together to radiation from a 220 keV Kelekett roentgen unit or from the 31 MeV betatron of The Norwegian Radium Hospital (WIDERÖE). The relative response of the two dosimeters, when exposed to betatron radiation through the plastic and copper equalizer, remained constant as the maximum energy was varied from 31 MeV to 16 MeV. However, the ratio of the crystal dosimeter response to that of the air chamber was much greater when irradiated with roentgen rays between 100 keV and 200 keV through a 0.5 mm Cu and 1.0 mm Al filter. Furthermore, this relative response varied between these energies showing a peak in the vicinity of 175 keV. At this energy its value was 4.67 times as great as the value for 31 MeV betatron radiation. The greater relative response of the crystal dosimeter to the roentgen radiation may be attributed to the larger photoelectric

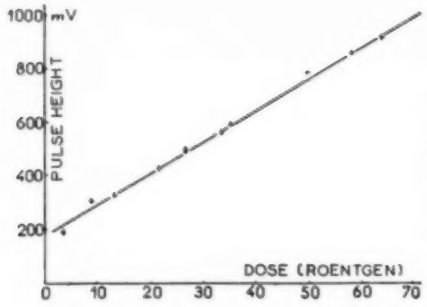

Diagram 1

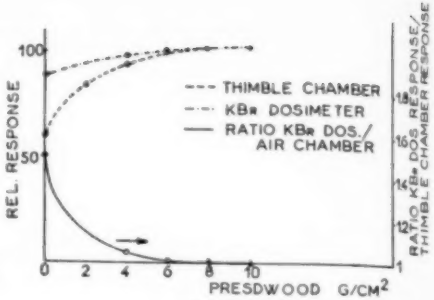

Diagram 2

Diagram 1. Dosimeter response to roentgen radiation.

Diagram 2. Response of the KBr crystal dosimeter and of an air thimble chamber for betatron radiation modified by 'Presdwood' filters. The crystal curve is normalized to coincide with the thimble chamber response at 7.8 g/cm, and both are set equal to 100.

absorption of potassium and bromine relative to that of air in this energy range.

In order to investigate the energy dependence further, the betatron spectrum with a maximum energy of 31 MeV was modified by using various thicknesses of 'Presdwood' filters. The results for a fixed betatron output of 100 r at the beam collimator exit are shown in Diagram 2. The smaller variation of the crystal dosimeter reading with absorber thickness is due mainly to the fact that the crystal used had a thickness of approximately 2.5 gm/cm² so that it provides a considerable amount of self-filtration. It is seen that the ratio of the responses of the two instruments approaches a constant value as the amount of absorber in the γ-ray beam increases. It can be expected therefore that the crystal dosimeter would give a result differing from that of an air chamber by only a constant factor for reasonable depths of absorbing material.

On this assumption the linear absorption coefficient in water and bone for the betatron γ-ray beam with a maximum energy of 31 MeV was measured with the crystal dosimeter using the arrangement shown in Fig. 2. The γ-ray beam in both cases was subject to the filtering action of the 3 mm (approx.) thick glass accelerator tube wall and the copper and plastic equalizer in the beam collimator. A discussion of the effect of this filtration on the betatron beam quality, based on theoretical considerations is given in the work of BRUSTAD and BAARLI. The maximum of the depth-dose distribution with a 12 × 15 cm field and F. S. D. of 102 cm was found to be at 4.5 cm, in agreement with other measurements made at this Institute using a thimble chamber. The linear absorption

coefficient, μ, for water between depths of 11 and 31 cm, was found to be $\mu = 0.0197$ cm^{-1} with a standard deviation of 0.0008 cm^{-1}. This can be compared with a value for 25 MeV betatron radiation with a target phantom distance of 100 cm (interpolated from data for 80 cm and 120 cm) of $\mu = 0.0203$ cm^{-1} obtained by LAUGHLIN et coll.

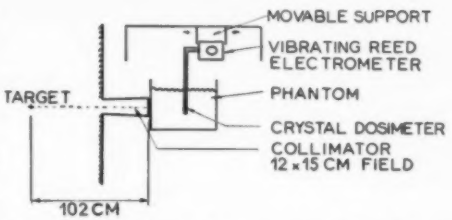

Fig. 2. Experimental arrangement for absorption coefficient measurements.

Linear absorption coefficient measurements were also made in an absorber of bone meal from bovine femur less marrow and epiphyses. Since moving the dosimeter through the bone meal leads to difficulties, measurements were taken with the dosimeter stationary and various depths of bone placed in the betatron beam. This resulted in a variation of target phantom distance from 110 cm to 137 cm which, however, should not cause an appreciable error in the absorption coefficient, since the difference in μ for target distances of 80 and 120 cm as measured by LAUGHLIN et coll. for water approximately two per cent. The linear absorption coefficient for bone of a specific density of 1.85 gm/cm^2 was found to be $\mu = 0.0452$ cm^{-1} with a standard deviation of 0.0009 cm^{-1}.

The absorption of γ-rays in the two media may be compared by the use of certain theoretical considerations. The mass absorption coefficient of water and bone relative to air has been calculated by LAUGHLIN for a continuous 'Bremsstrahlung' spectrum modified by absorption in a porcelain accelerating tube wall. Interpolating between his results for 20 MeV and 70 MeV, the ratio of the mass absorption coefficients in bone and water of unit density for 31 MeV 'Bremsstrahlung' is calculated to be 1.14. To this ratio must be added a small correction due to the fact that our bone meal lost a certain amount of water during the course of experimentation, as was evidenced by a change in specific density. Applying this correction, the ratio of the linear absorption coefficients for bone (with a density of 1.85) and water is calculated to be 2.15. This is to be compared with the value 2.27 found experimentally. In view of the uncertainties in calculation and the experimental errors, the agreement is satisfactory. On the basis of work at this Institute on the absorption of γ-rays with an energy spread of a few MeV, one can assign to the measured linear absorption coefficient, a mean effective energy such that monoenergetic γ-rays of this energy have the same absorption (BRUSTAD and BAARLI). The experimental values for the linear absorption coefficient in bone and water correspond to a mean effective energy of 13 MeV and 13.9 MeV respectively.

The substantial agreement obtained between measurements of the linear absorption coefficient with an air chamber and a KBr dosimeter in spite of their differing energy dependence lends support to the view that the shape of the total spectrum of the betatron beam changes relatively slowly with depth for appreciable absorber depths. A crystal dosimeter of the type described using RbI or CsI crystals would, on account of their larger average atomic number, have a greater relative response to low energy quanta, and would therefore be of use in investigating the behaviour of the low energy component of the total radiation spectrum. This would be a relatively simple way to obtain some experimental information on the shape of the radiation spectrum, which is rather difficult to determine without quite complicated measuring techniques.

Acknowledgements

I should like to thank the members of the Institute for their help and cooperation. Particular thanks are due to J. Baarli, under whose direction this work was carried out, and T. Brustad for his many stimulating suggestions.

SUMMARY

The use and behaviour of alkali halide crystals in measuring roentgen and γ radiation was investigated. Dosimeters containing single crystals and powdered crystals of KBr were constructed and irradiated with 175 keV roentgen and 31 MeV γ-rays 'Bremsstrahlung' from the Institute's betatron. The response of this dosimeter relative to a Victoreen type thimble chamber was found to be approximately five times greater when irradiated with 175 keV roentgen rays than when irradiated by 31 MeV 'Bremsstrahlung'. The response ratio was unchanged by lowering the maximum energy of the betatron from 31 MeV to 16 MeV.

The measurement of the linear absorption coefficient of 31 MeV 'Bremsstrahlung' in water and bone was carried out. The results agreed with values obtained with an air chamber in the case of water, and were in agreement with theoretical expectations in the case of bone.

ZUSAMMENFASSUNG

Die Benutzung und das Verhalten effektiver Alkalikristalle bei der Messung von Röntgen- und Gammastrahlung ist untersucht worden. Dosimeter mit einzelnen Kristallen und mit pulverisierten Kaliumbromidkristallen sind konstruiert und mit 175 KeV Röntgenstrahlung und 31 MeV Bremsstrahlung vom Betatron des Institutes bestrahlt worden. Der Ausschlag des Dosimeters im Verhältnis zu einer Fingerhutkammer vom Victoreentypus war annähernd 5 mal grösser bei Bestrahlung mit 175 KeV Röntgenstrahlen als bei Bestrahlung mit 31 MeV Bremsstrahlen. Das Verhältnis der Ausschläge war bei Herabsetzung des Energiemaximums des Betatronen von 31 MeV auf 16 MeV unverändert.

Die Messung des lineären Absorptionskoeffizienten der 31 MeV Bremsstrahlung in Wasser und Knochen ist durchgeführt worden. Die Ergebnisse stimmen für Wasser mit den mit einer Luftkammer erhaltenen Werten überein; für Knochen standen sie mit den theoretischen Berechnungen im Einklang.

RÉSUMÉ

L'auteur a fait des recherches sur l'emploi et les propriétés des cristaux d'halogénures alcalins pour la mesure des rayonnements roentgen et gamma. Des dosimètres contenant un cristal unique ou une poudre cristalline de KBr ont été construits et irradiés par des rayons roentgen de 175 keV et le rayonnement de «Bremsstrahlung» de 31 MeV du bêtatron de l'Institut. Comparée à celle d'une chambre dé à coudre type Victoreen, la réponse de ce dosimètre s'est montrée approximativement cinq fois plus élevée quand il est irradié par les rayons roentgen de 175 keV que quand il est irradié par la «Bremsstrahlung» de 31 MeV. Le rapport des réponses restait inchangé quand on abaissait l'énergie maximum du bêtatron de 31 MeV à 16 MeV.

L'auteur a mesuré le coefficient d'absorption linéaire de la «Bremsstrahlung» de 31 MeV dans l'eau et dans l'os. Les résultats ont concordé avec les valeurs obtenues avec une chambre d'ionisation à air dans le cas de l'eau, et avec les prévisions théoriques dans le cas de l'os.

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BOOK REVIEWS

RADIUM THERAPY. Its physical aspects and extensions with radioactive isotopes. Second edition. By C. W. Wilson. 286 pp., 71 figs., 21 plates. Baillière, Tindall & Cox, London 1956. 37s. 6d.

The rapid developments in radiotherapy and radiologic physics make a new edition of Wilson's well-known book most welcome. This does not mean that the bulk of the material in the first edition has become obsolete; it is in fact included in the new edition without much change. It refers particularly to the chapters on radium and its decay products, dose measuring methods and instruments, dose units, and established methods of dosage planning and calculation, including the Paterson-Parker dosage system for different types of radium therapy, which is fully described and illustrated by a number of examples. All this material is, in the second edition, supplemented by new dosimetric methods and dose units and, above all, the artificially radioactive isotopes which have, by their flexibility and the large quantities in which some of them may now be obtained, opened a number of new possibilities in radiotherapy. It should be noted that the book deals exclusively with methods in which the radioactive substances are more or less permanently sealed in and under the control of the radiotherapist. Procedures in which the substances are injected or ingested, whereafter control of their further fate in the body is lost, are not treated.

The book ends with a chapter on radiation protection and is completed by a number of tables useful in the application of various methods. The work is not confined to theory but is full of practical details on methods and materials. It is thus valuable for the various categories of people engaged in radiotherapy — therapists, physicists, and technicians. Such errors as have been found are only of minor importance and include certain references, and some of the numerals on p. 5 for the weight of one curie of different members of the uranium—radium family.

Sven Benner

Hämodynamik des Herzens im Röntgenbild. Von P. Thurn. Georg Thieme Verlag, Stuttgart 1956. 167 S. DM. 48: —

This book seems to be written with claims on reliability, and it is therefore unfortunate that no supporting evidences are given for any of the statements made. Practically no case material or diagnostic verifications are presented and the thoroughness, which is otherwise so characteristic of German scientific work, is here absent. These short-comings tend to obscure the valuable features the book may possess. The general impression conveyed is that the author has not succeeded in penetrating the mysteries of hemodynamics, which may have been due to the fact that the author has been so absorbed in his own ideas that he has been led to ignore the progress made in other countries during the past 5 years. The reviewer feels obliged to warn against uncritical reading of this book, because anyone who is not very well aquainted with the subject might easily be led astray.

Sven Roland Kjellberg